DOCUMENT RESUME

ED 256 048 EA 017 673

AUTHOR	Ruegg, Rosalie T.; Marshall, Harold E.
TITLE	Economic Evaluation of Building Design, Construction, Operation and Maintenance. Instructor's Manual.
INSTITUTION	National Bureau of Standards (DOC), Washington, D.C.
REPORT NO	NBS-TN-1194
PUB DATE	Jun 84
NOTE	321p.; For the workbook for this seminar, see EA 017 674.
AVAILABLE FROM	Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 (GPO Stock No. 003-003-02597-8; $8.00).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01/PC13 Plus Postage.
DESCRIPTORS	*Building Design; *Building Operation; *Cost Effectiveness; Decision Making; Energy Conservation; *Evaluation Methods; Facility Guidelines; Government Publications; *Life Cycle Costing; Maintenance; *Problem Solving; Structural Elements (Construction); Teaching Guides; Visual Aids
IDENTIFIERS	*Economic Evaluations

ABSTRACT

This instructor's manual describes each section of a 3-day technical seminar on how to measure the economic impact of alternative designs, systems, and operation and maintenance strategies in federal buildings. The manual was prepared to help instructors of the General Services Administration conduct technically sound and comprehensive seminars. For each technical session, the manual provides an introduction explaining the purpose of that session followed by copies of each visual and an outline of the commentary that would accompany that visual. The seminar covers the fundamentals of lifecycle cost, benefit-to-cost ratio, savings-to-investment ratio, internal rate of return, and payback analyses; sensitivity and probability analyses; break-even analysis; replacement decisions; and the solution of sample building problems that illustrate these economic evaluation methods. The sessions alternate between presentations of economic theory required for evaluating problems and actual problems that illustrate the economic evaluations in practice. Real building design problems with an emphasis on energy conservation are presented for individual and group solutions. The manual describes step by step how to present the problems and how to solve them. It presupposes an existing familiarity of the instructors with the basic concepts and evaluation techniques used in the seminars. (The appendixes contain a sample 3-day agenda and a selective bibliography of 13 citations that describe in detail the economic methods presented.) (Author)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

INSTRUCTOR'S MANUAL

Economic Evaluation of Building Design, Construction, Operation and Maintenance

ED256048

EA 017 673

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☒ This document has been reproduced as received from the person or organization originating it.

☐ Minor changes have been made to improve reproduction quality.

- Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NBS Technical Note 1194

The National Bureau of Standards[1] was established by an act of Congress on March 3, 1901. The Bureau's overall goal is to strengthen and advance the nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau's technical work is performed by the National Measurement Laboratory, the National Engineering Laboratory, the Institute for Computer Sciences and Technology, and the Center for Materials Science.

The National Measurement Laboratory

Provides the national system of physical and chemical measurement; coordinates the system with measurement systems of other nations and furnishes essential services leading to accurate and uniform physical and chemical measurement throughout the Nation's scientific community, industry, and commerce; provides advisory and research services to other Government agencies; conducts physical and chemical research; develops, produces, and distributes Standard Reference Materials; and provides calibration services. The Laboratory consists of the following centers:

- Basic Standards[2]
- Radiation Research
- Chemical Physics
- Analytical Chemistry

The National Engineering Laboratory

Provides technology and technical services to the public and private sectors to address national needs and to solve national problems; conducts research in engineering and applied science in support of these efforts; builds and maintains competence in the necessary disciplines required to carry out this research and technical service; develops engineering data and measurement capabilities; provides engineering measurement traceability services; develops test methods and proposes engineering standards and code changes; develops and proposes new engineering practices; and develops and improves mechanisms to transfer results of its research to the ultimate user. The Laboratory consists of the following centers:

- Applied Mathematics
- Electronics and Electrical Engineering[2]
- Manufacturing Engineering
- Building Technology
- Fire Research
- Chemical Engineering[2]

The Institute for Computer Sciences and Technology

Conducts research and provides scientific and technical services to aid Federal agencies in the selection, acquisition, application, and use of computer technology to improve effectiveness and economy in Government operations in accordance with Public Law 89-306 (40 U.S.C. 759), relevant Executive Orders, and other directives; carries out this mission by managing the Federal Information Processing Standards Program, developing Federal ADP standards guidelines, and managing Federal participation in ADP voluntary standardization activities; provides scientific and technological advisory services and assistance to Federal agencies; and provides the technical foundation for computer-related policies of the Federal Government. The Institute consists of the following centers:

- Programming Science and Technology
- Computer Systems Engineering

The Center for Materials Science

Conducts research and provides measurements, data, standards, reference materials, quantitative understanding and other technical information fundamental to the processing, structure, properties and performance of materials; addresses the scientific basis for new advanced materials technologies; plans research around cross-country scientific themes such as nondestructive evaluation and phase diagram development; oversees Bureau-wide technical programs in nuclear reactor radiation research and nondestructive evaluation; and broadly disseminates generic technical information resulting from its programs. The Center consists of the following Divisions:

- Inorganic Materials
- Fracture and Deformation[3]
- Polymers
- Metallurgy
- Reactor Radiation

BEST COPY AVAILABLE

---

[1] Headquarters and Laboratories at Gaithersburg, MD, unless otherwise noted; mailing address Gaithersburg, MD 20899.

[2] Some divisions within the center are located at Boulder, CO 80303.

[3] Located at Boulder, CO, with some elements at Gaithersburg, MD.

NBS Technical
Note 1194

INSTRUCTOR'S MANUAL

Economic Evaluation of Building Design, Construction, Operation and Maintenance

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Applied Mathematics
Operations Research Division
Gaithersburg, MD 20899

Prepared by:
Rosalie T. Ruegg and
Harold E. Marshall
Operations Research Division
Center for Applied Mathematics
National Bureau of Standards
U.S. Department of Commerce

Prepared for:
Design Programs Branch
Public Building Service
General Services Administration
Washington, DC 20405

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, Secretary
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, Director
Issued June 1984

National Bureau of Standards Technical Note 1194
Natl. Bur. Stand. (U.S.), Tech. Note 1194, 317 pages (June 1984)
CODEN: NBTNAE

U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON: 1984

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402

ABSTRACT

This instructor's manual describes each section of a three-day technical seminar on how to measure the economic impact of alternative designs, systems, and operation and maintenance strategies in Federal buildings. The manual was prepared to help instructors of the General Services Administration conduct technically sound and comprehensive seminars. For each technical session, the manual provides an introduction explaining the purpose of that session followed by copies of each visual and an outline of the commentary that would accompany that visual. The seminar covers the fundamentals of life-cycle cost, benefit-to-cost ratio, savings-to-investment ratio, internal rate of return, and payback analyses; sensitivity and probability analyses; break-even analysis; replacement decisions; and the solution of sample building problems that illustrate these economic evaluation methods. The sessions alternate between presentations of economic theory required for evaluating problems and actual problems that illustrate the economic evaluations in practice. Real building design problems with an emphasis on energy conservation are presented for individual and group solutions. The manual describes step-by-step how to present the problems and how to solve them. It presupposes an existing familiarity of the instructors with the basic concepts and evaluation techniques used in the seminars.

PREFACE

Rising costs of energy and increasingly constrained construction and operating budgets have forced building owners and operators to give increasing attention to the life-cycle consequences of building decisions. Life-cycle costing and benefit-cost analysis are two of the economic techniques that have been used to make more economically efficient building decisions. The purpose of this manual is to help instructors present a technically sound and comprehensive seminar on the economic evaluation of buildings. The objective of the seminar is to provide participants with a working knowledge of economic evaluation procedures for making cost-effective decisions related to new construction and building retrofit.

This manual was developed to help instructors of the General Services Administration (GSA) present a technically sound and comprehensive seminar to Federal employees. The visuals and problems in the manual have been field tested in several courses taught by the authors in GSA regions throughout the United States. Approaches and problems presented herein have also been tested in other courses presented by the authors for the Department of Energy and the University of California Extension Service. Thanks are due the many students who have taken these courses and suggested improved ways of teaching them.

The authors also wish to thank the members of the American Society for Testing and Materials (ASTM) E06.81 Subcommittee on Building Economics. Through their discussions and critiques of economic methods in the standards development process, they have provided insight to many of the issues treated in this manual. (Instructors using this manual who would like to learn more about ASTM's work in building economics should contact Kenneth Pearson, ASTM Standards Development Division, 1916 Race Street, Philadelphia, PA 19103.)

Special thanks are also due David Eakin of the Design Programs Branch, GSA, for his painstaking attention to our development of a course that meets the needs of GSA. Barbara Lippiatt of NBS helped revise slides and problems for the manual, and Laurene Linsenmayer patiently typed numerous drafts prior to final printing. Finally, thanks are due the many persons at the National Bureau of Standards who spent time with the authors discussing economic issues and suggesting problems that the manual should address.

TABLE OF CONTENTS

Page

ABSTRACT. iii

PREFACE v

1. INTRODUCTION. 1-1

2. Slide Presentation: Seminar Introduction 2-1

3. Slide Presentation: LCC Examples 3-1

4. Slide Presentation: Fundamentals of Benefit-Cost and LCC Analysis. 4-1

5. Problems: Discounting and LCC Analysis Using Discount Factor Tables 5-1

6. Presentation: LCC, NS, BCR, SIR, IRR, and PB Analysis. 6-1

7. Problem: Pipe Insulation Retrofit. 7-1

8. Problem: Programmable Time Clock 8-1

9. Backup Problem: New Building Design. 9-1

10. Presentation: Determining Project Priority 10-1

11. Problem: Water-Conservation Problem. 11-1

12. Presentation: Project Design, Sizing, and Selection. 12-1

13. Presentation: Treatment of Inflation 13-1

14. Team Problem: Planning an Energy Conservation Package. 14-1

15. Presentation: Sensitivity Analysis 15-1

16. Problem: Sensitivity Analysis. 16-1

17. Presentation: Probability Analysis 17-1

18. Team Problem: Probability Analysis 18-1

19. Presentation: Break-Even Analysis. 19-1

20. Team Problem: Break-Even Analysis. 20-1

21. Problem: Computer Room Waste Heat Recovery 21-1

22. Presentation: Replacement, Retirement, and Obsolescence. 22-1

23. Team Problem: Determining Optimal Retirement of Equipment. 23-1

24. Team Critique of an Economic Evaluation Report. 24-1

APPENDIX A. Sample Three-Day Agenda A-1

APPENDIX B. Selected References B-1

Section 1

1. INTRODUCTION

This instructor's manual provides an approach to teaching a three-day technical seminar on how to measure the economic impact of alternative designs, systems, and operation and maintenance strategies in Federal buildings. The purpose of the manual is to help instructors of the General Services Administration (GSA) present a technically sound and comprehensive seminar. The objectives of the seminar are to provide participants with a working knowledge of economic evaluation procedures as mandated for the Federal government in making building decisions, and to improve the ability of participants to deal with decision making responsibilities related to cost management and selection of buildings for new construction and retrofit applications.

The seminar material has been developed particularly for building design engineers and architects, project planning and programming staff, managers of building operating programs, building evaluation personnel, contract coordinators and negotiators for building studies and design, building construction estimators, and private contractors involved in GSA construction projects.

The sessions alternate between lecture presentations and classroom problems. The presentations relate economic theory to the solution of practical building problems and provide the participant with fundamental theory and methods necessary to make economic evaluations of buildings.

The classroom problems start with simple discounting exercises and conclude with comprehensive analyses of complex building projects. Both new building and retrofit problems are considered. Some problems are presented and then solved by the instructors, whereas others are presented to the class to be solved individually or in teams.

The approach is to alternate between presenting theory and methods and solving problems. The seminar sessions are arranged in increasing order of comprehensiveness and complexity. Each section builds on those preceding to enhance the participant's understanding of economic methods and how to apply them to real-life building problems.

It is assumed that instructors using this manual will have a thorough understanding at the outset of the theory and methods used in the seminar. The manual structures each session of the course, describes the message or point that each session is intended to convey, provides annotated copies of visuals used in the seminar, and explains how to present and solve the problems. Within the framework provided, instructors may wish to develop their own notes and lecture materials.

Whereas the ordering and number of sessions are designed for a three-day seminar, shorter seminars with a different sequence of sessions could be developed from this manual. The only sequence which should be preserved is that of explaining the economic method of evaluation before presenting a problem for class solution requiring that method. A sample three-day agenda is provided in Appendix A.

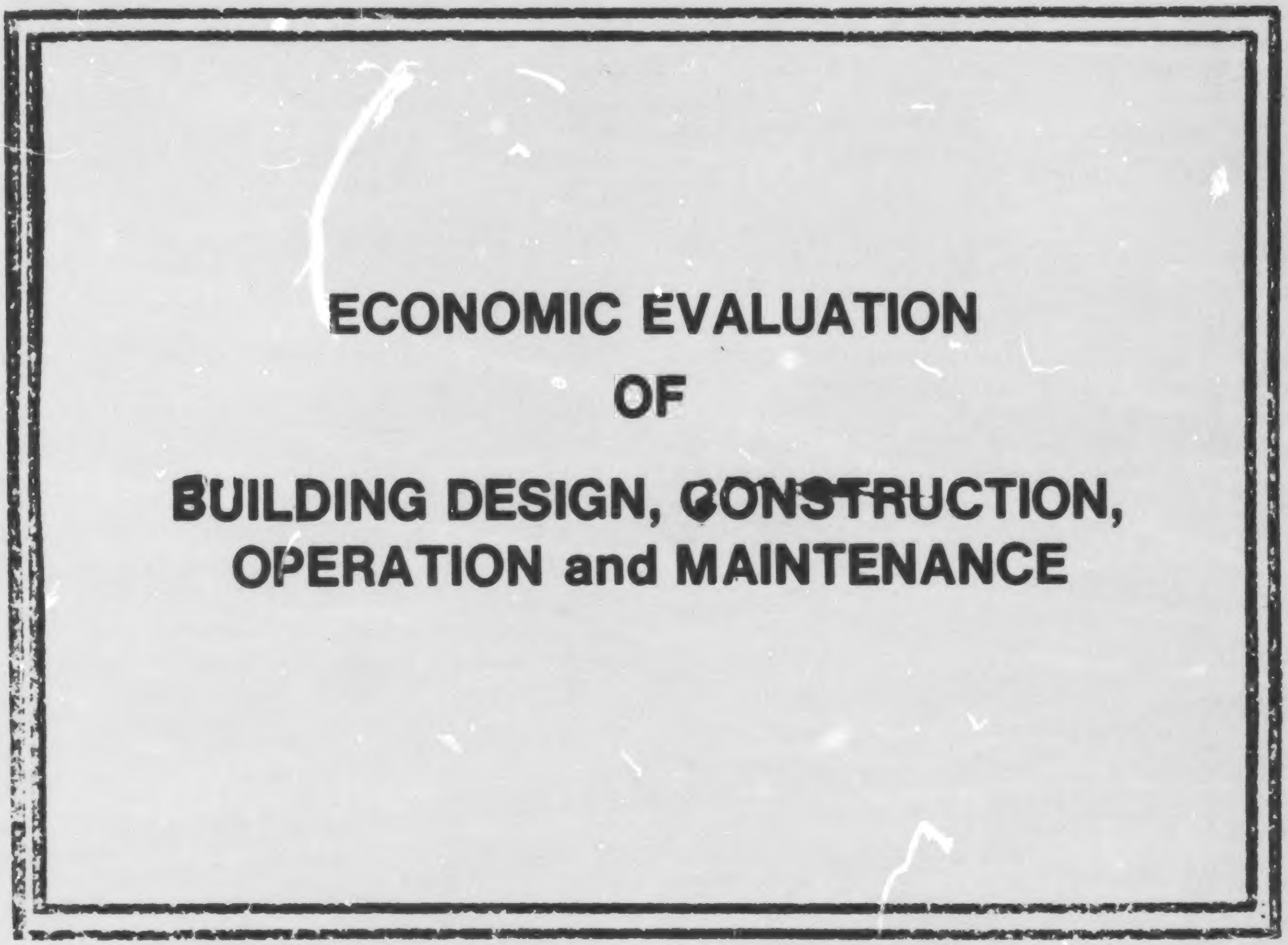
A selective bibliography concludes this manual. It provides instructors a guide to the literature which describes in detail the economic methods presented.

Section 2

Slide Presentation: Seminar Introduction

This first session (1) explains the purposes of the seminar, (2) identifies the uses of economic analysis in decision making, and (3) discusses the Federal LCC Rule (10 CFR, Part 436) as a required procedure for GSA and other Federal agencies. (A detailed discussion of specific GSA requirements may be beneficial later in the seminar, after a general understanding and an appreciation of evaluation techniques, procedures, and applications have been established.)

Slide 1

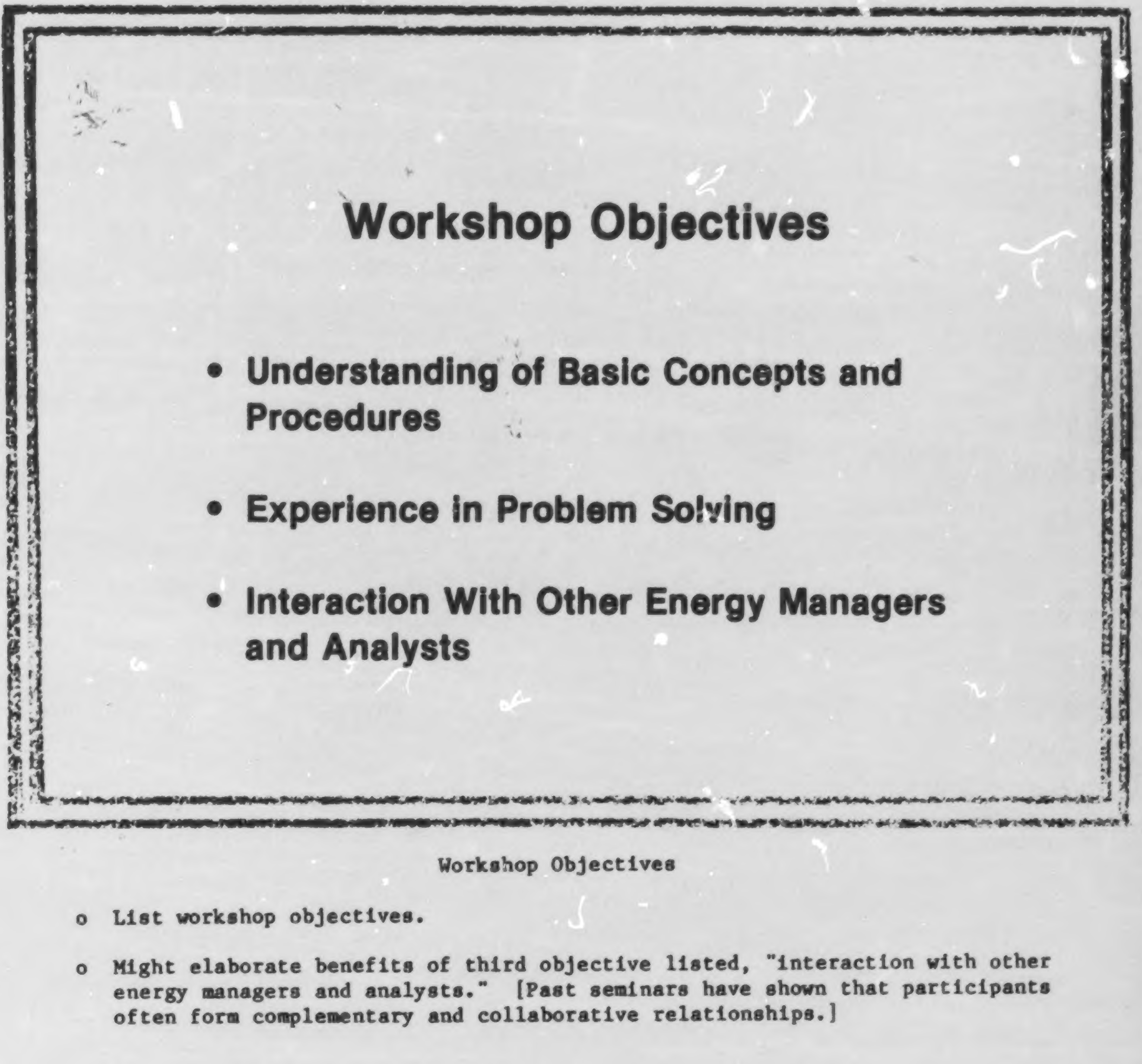


ECONOMIC EVALUATION
OF
BUILDING DESIGN, CONSTRUCTION, OPERATION and MAINTENANCE

Economic Evaluation of Building Design, Construction, Operation, and Maintenance

- Introduce speakers.
- Have participants introduce themselves, stating their area of work and particular interest and experience in life-cycle costings.
- Briefly introduce the materials that have been distributed:
  - --The Workbook contains some OMB and GSA reference documents, brief explanations of techniques treated in the seminar, problems, and worksheets. The Workbook does not correspond exactly to the lecture sequence; the participant will be directed to the relevant sections of the Workbook as needed.
  - --Handbook 135 amplifies the Federal Life-Cycle Costing Rules for Evaluating Energy Conservation, and will be used as a source of energy price data and a general reference source.

Slide 2



Workshop Objectives

- Understanding of Basic Concepts and Procedures
- Experience in Problem Solving
- Interaction With Other Energy Managers and Analysts

Workshop Objectives

- List workshop objectives.
- Might elaborate benefits of third objective listed, "interaction with other energy managers and analysts." [Past seminars have shown that participants often form complementary and collaborative relationships.]

Slide 3

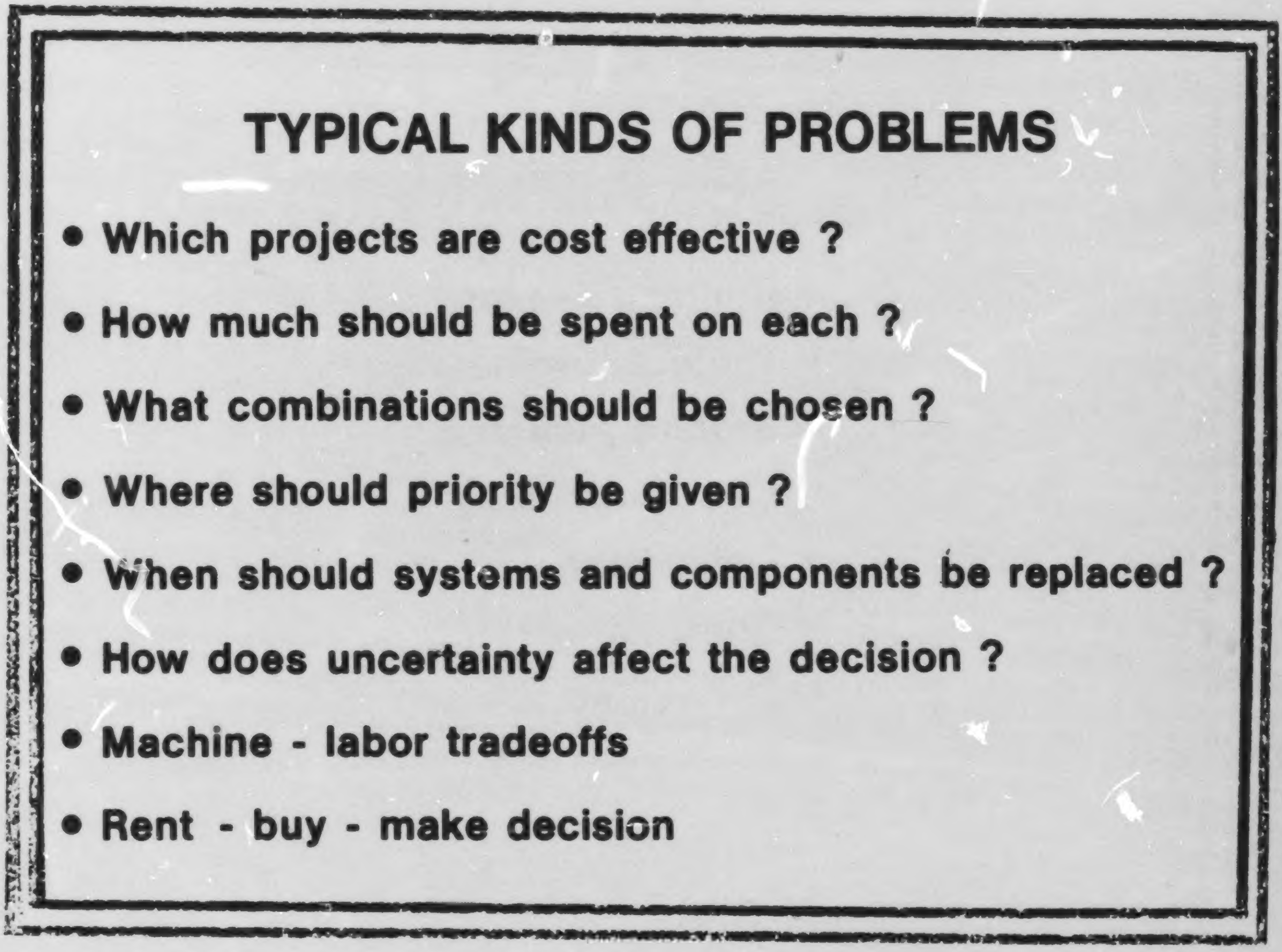
TOPICS

- Analysis Techniques
- Model Formulation
- Data and Assumptions
- Problem Solving

Topics

- List the major topics to be covered.
- Explain that by the end of the seminar the participants will know the major economic analysis techniques for evaluating capital investment projects, will be able to develop models for problem solving, will know what data and assumptions are needed to exercise various models, and will be able to carry out the computations to solve the problem.

Slide 4



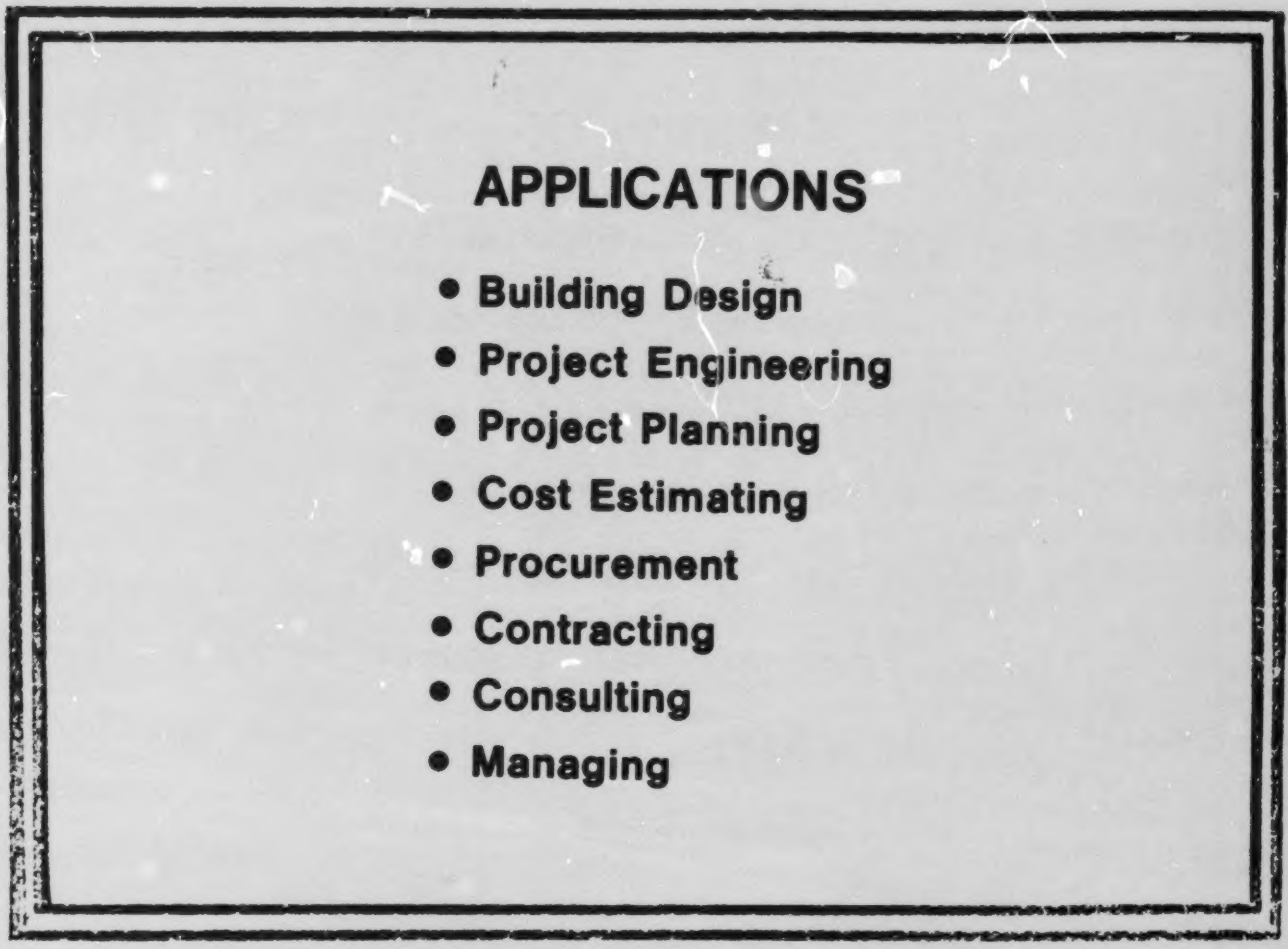
TYPICAL KINDS OF PROBLEMS

- Which projects are cost effective ?
- How much should be spent on each ?
- What combinations should be chosen ?
- Where should priority be given ?
- When should systems and components be replaced ?
- How does uncertainty affect the decision ?
- Machine - labor tradeoffs
- Rent - buy - make decision

Typical Kinds of Problems

- Explain that the techniques covered can be used to solve different kinds of problems.
- Go through the listing of the different kinds of problems and give examples where needed for clarity.

Slide 5



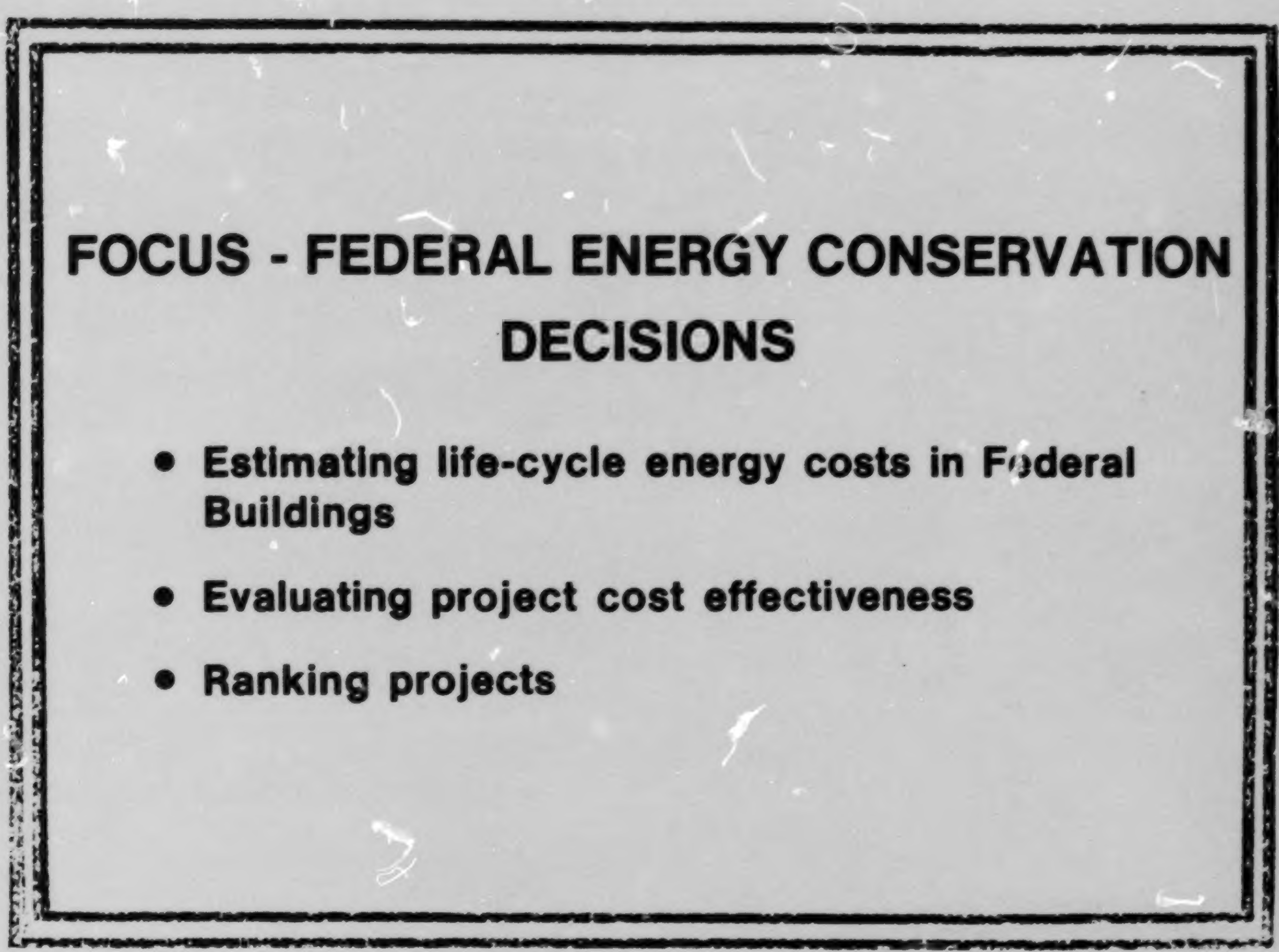
APPLICATIONS

- Building Design
- Project Engineering
- Project Planning
- Cost Estimating
- Procurement
- Contracting
- Consulting
- Managing

Applications

- o Explain that the problem-solving techniques can be applied in a number of different applications and will be useful to people in different professions.
- o Go through the list and give a few examples.

Slide 6



FOCUS - FEDERAL ENERGY CONSERVATION DECISIONS

- Estimating life-cycle energy costs in Federal Buildings
- Evaluating project cost effectiveness
- Ranking projects

Focus--Federal Energy Conservation Decisions

- o Note that while the techniques and general approach are applicable to many types of investment problems, the focus of the seminar is on evaluating energy conservation projects for Federal buildings.
- o Explain that the methods and procedures presented are compatible with the Federal Life-Cycle Costing Rules that have been developed in compliance with legislation and Executive Order [Section 381(a)(2) of the Energy Policy and Conservation Act, Title V of the National Energy Conservation Policy Act, 92 Stat. 3275, as amended by Section 405 of the Energy Security Act, 94 Stat. 611; and Section 10 of Presidential Executive Order 11912, as amended by Executive Order 12003.]
- o The Federal Life-Cycle Costing Rules are established in Subpart A of Part 436 of Title 10 of the Code of Federal Regulations.

Section 3

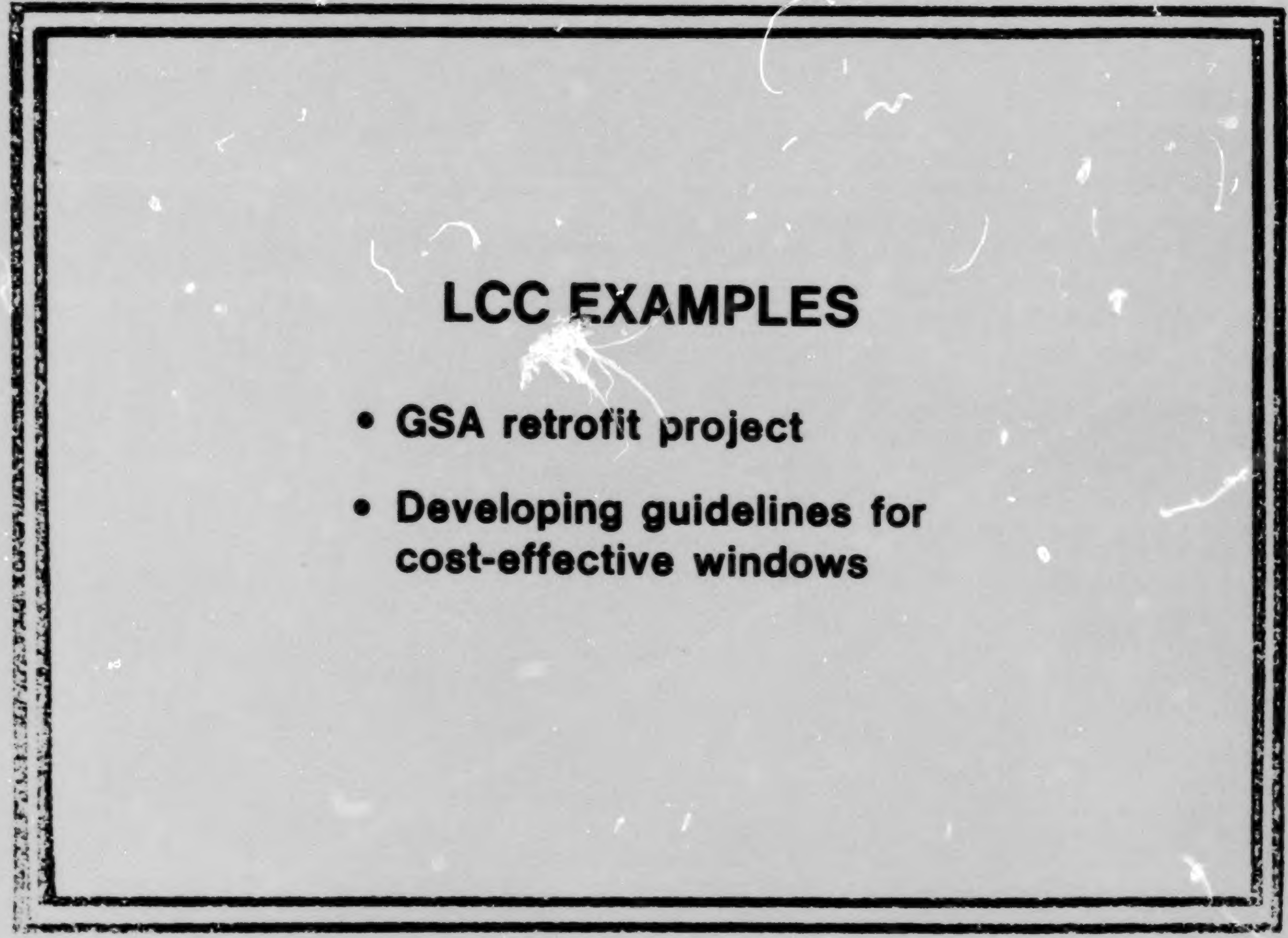
Slide Presentation: LCC Examples

The objectives of this lecture are (1) to provide a perspective of life-cycle cost (LCC) analysis in its entirety before examining in detail the parts, (2) to establish at the outset an appreciation of how economic analysis can improve the quality of decision making by systematically structuring the problem, identifying the options, and integrating the factors important to the outcome of the decision; (3) to serve as a means of identifying and discussing some of the concerns and issues in Benefit-Cost (B-C) and LCC analysis; and (4) to distinguish between the use of B-C and LCC analyses to (a) evaluate a single project and (b) to derive generalizable guidelines for building decisions.

Two examples are presented in brief, with the focus on the reason for the analysis, the general approach, and interpretation of results, rather than on the details of how to do the examples. The first example is for the retrofit of a Federal building. The second example is a generic-type study of window selection and use.

[Note: The instructor may wish to substitute other examples that achieve the same objectives.]

Slide 1



LCC EXAMPLES

- GSA retrofit project
- Developing guidelines for cost-effective windows

LCC Examples

- o Explain the objectives of this session (see preceding notes).
- o Identify the two case studies.
- o Distinguish between a study of a specific project and a generic-type study to develop general guidelines.

Slide 2

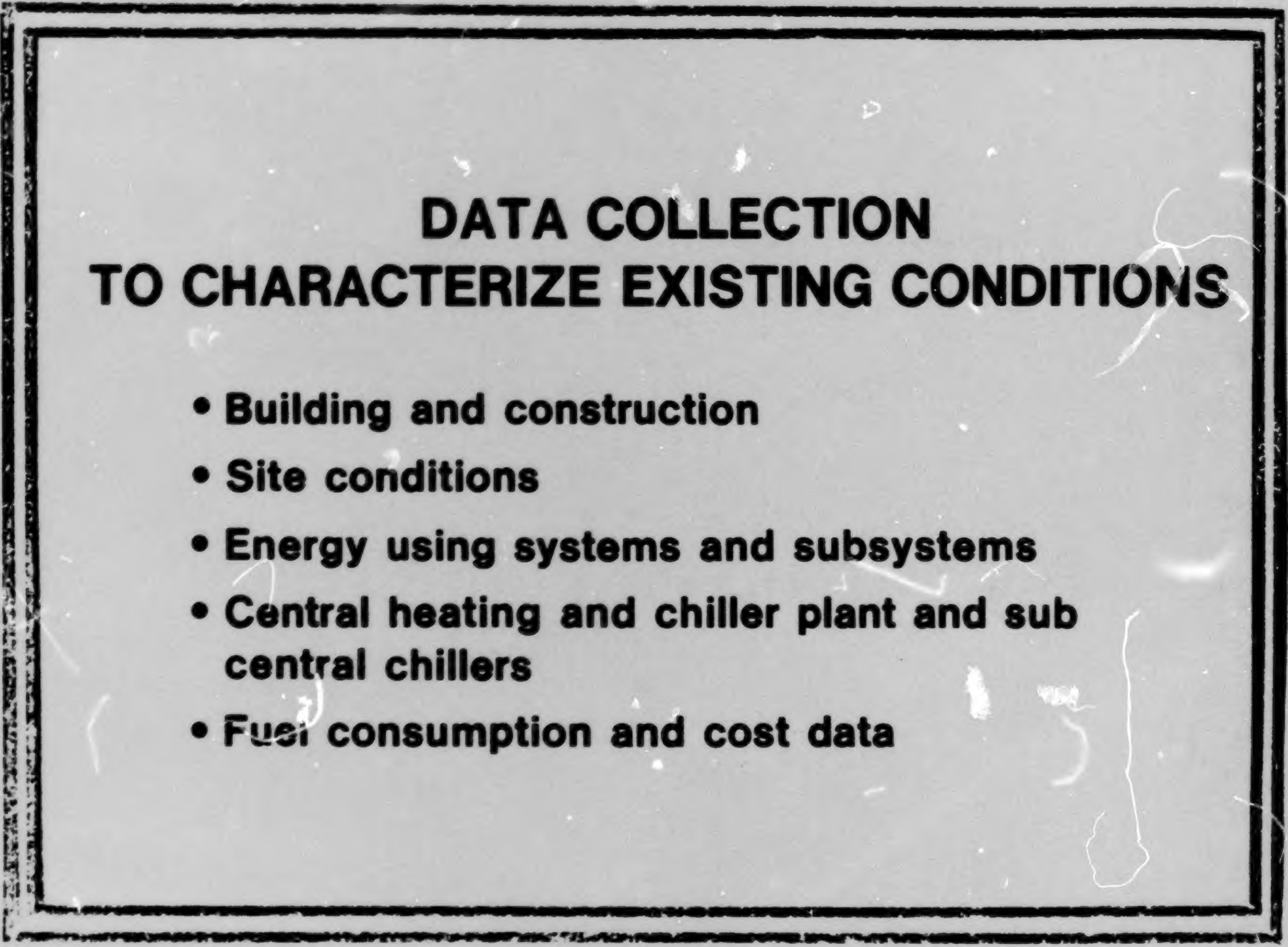
ENERGY CONSERVATION STUDY OF A FEDERAL BUILDING

OBJECTIVE: Reduce Energy Consumption by 20%

Energy Conservation Study of a Federal Building

- Note that this is a study of a specific building for purpose of retrofitting it.
- Give background--The study was conducted in response to requirements of the Federal Energy Management Program (FEMP) to reduce energy consumption in Federal buildings by 20 percent.
- Note that the study was performed by a private consultant; no verification was made of the computations--only an overview of the general approach and nature of the findings is intended.
- The study also evaluated water conservation options, but those are not included in this presentation.

Slide 3



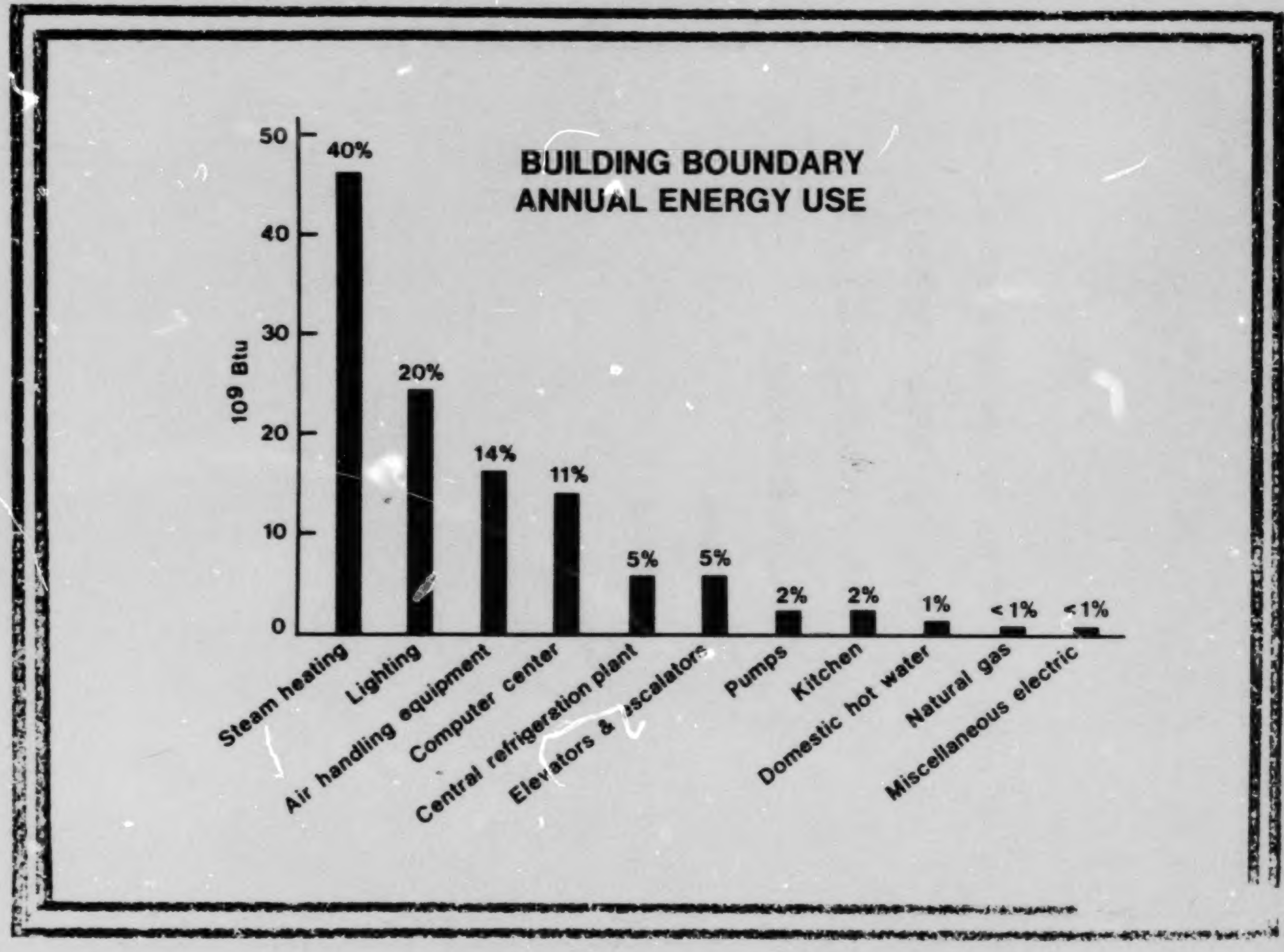
DATA COLLECTION
TO CHARACTERIZE EXISTING CONDITIONS

- **Building and construction**
- **Site conditions**
- **Energy using systems and subsystems**
- **Central heating and chiller plant and sub central chillers**
- **Fuel consumption and cost data**

Data Collection to Characterize Existing Conditions

- o Note that an initial phase of the study entailed characterizing existing systems and subsystems.
- o This is necessary to identify potential alternatives.
- o This is necessary to establish a baseline LCC against which alternatives can be evaluated.

Slide 4



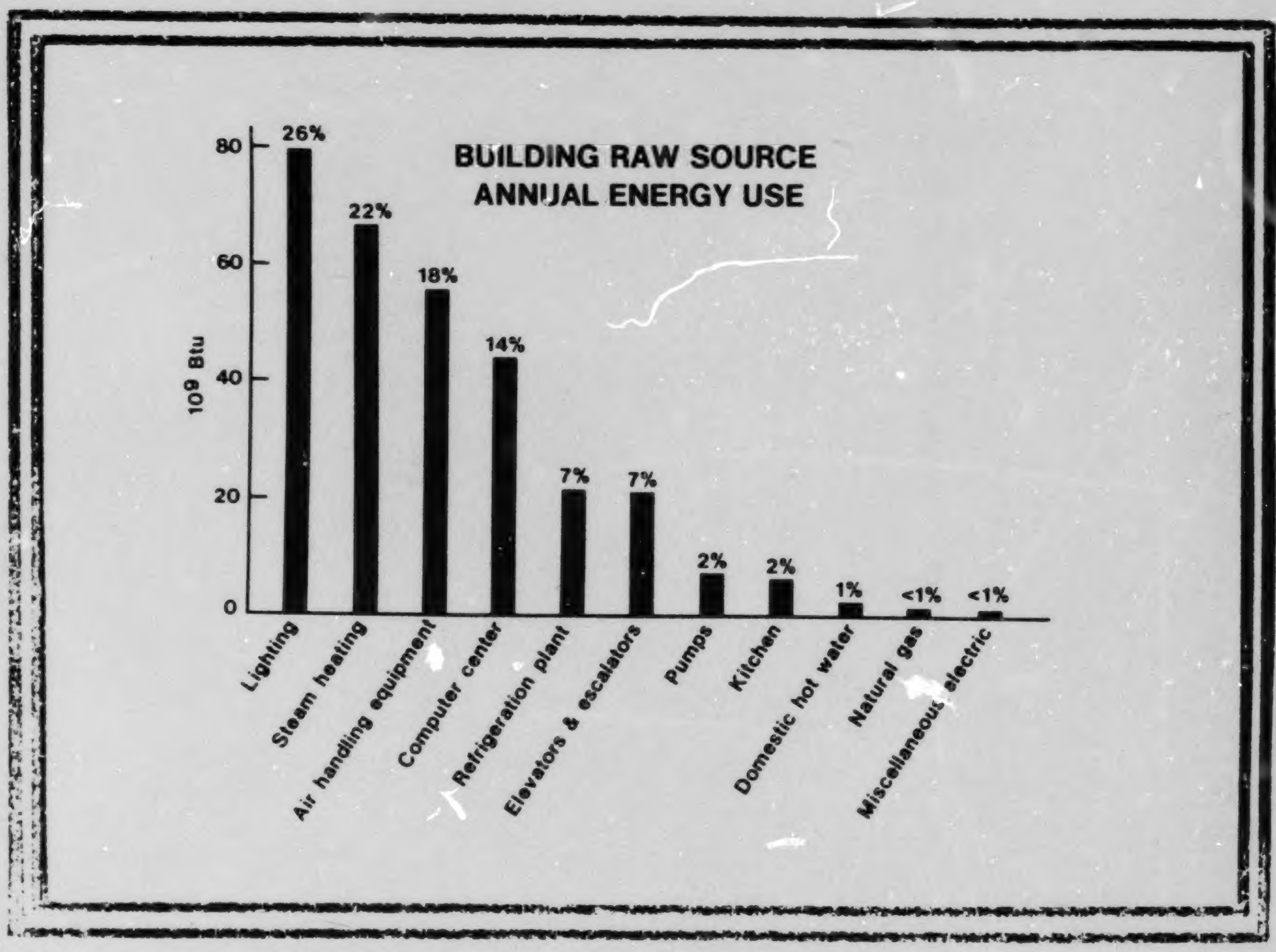
Building Boundary Annual Energy Use

- Note that this plus the following 2 slides are examples of the effort to characterize existing conditions. The first measures purchased energy at the boundary of the building, the second measures the quantity of energy at the source of production.

- The focus on energy usage in terms of quantity rather than cost at this stage of the analysis reflects the fact that the primary FEMP goal is stated in terms of reducing the quantity of energy used.

- The vertical bars indicate in 10^9Btu's the annual boundary energy use for each purpose indicated on the horizontal axis, and the percentage number at the top of each bar expresses that usage as a percent of the total building usage.

Slide 5


BUILDING RAW SOURCE ANNUAL ENERGY USE

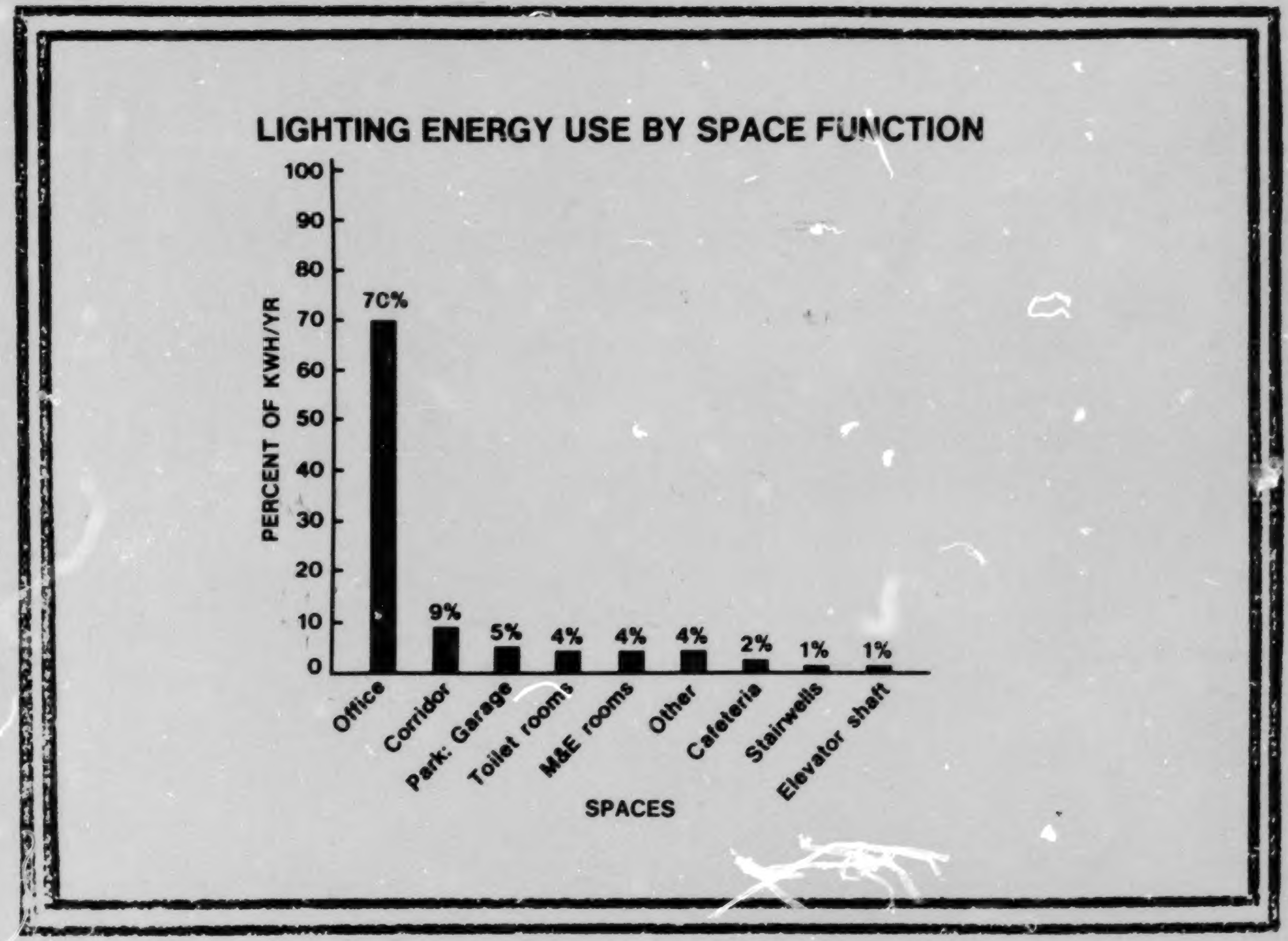
Building Raw Source Annual Energy Use

- This is another example of characterizing existing conditions, but this time going back to the source to measure energy use. For example, the Btu's for lighting are measured here in terms of the initial fuel used to produce the electricity that is purchased for lighting.

- Note the switch that occurs between lighting and heating as the predominant user of energy when energy is measured in terms of "raw source" Btu's versus "boundary" Btu's.

- Explain in this context the possible conflict that can arise between saving energy versus saving dollars.

Slide 6



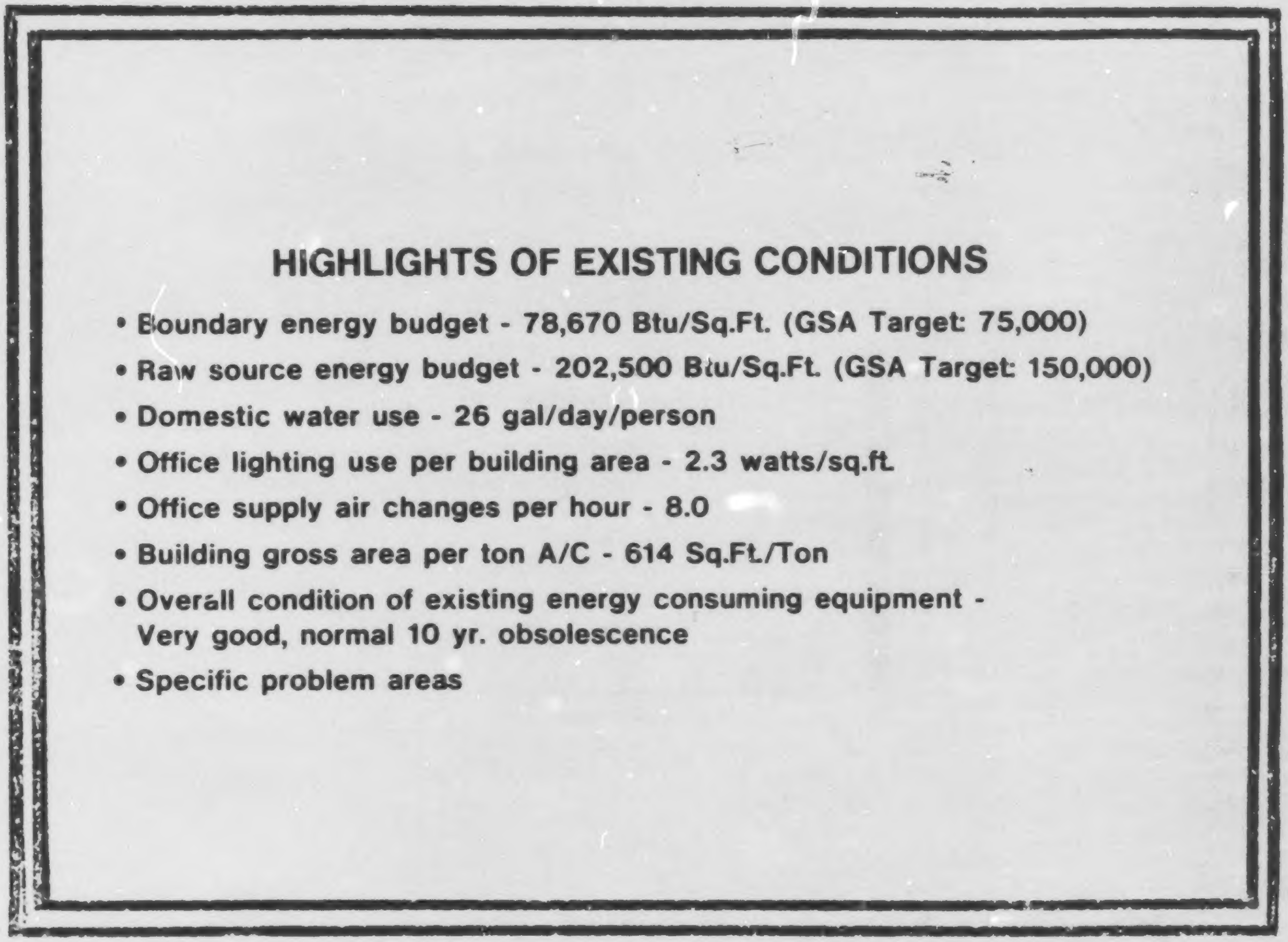
LIGHTING ENERGY USE BY SPACE FUNCTION

Lighting Energy Use By Space Function

- This is an example of a second level of detail in characterizing existing conditions.

- Further detail included, for example, lamp types, their maintenance and operational schedules, and their performance in terms of lighting levels.

Slide 7



HIGHLIGHTS OF EXISTING CONDITIONS

- Boundary energy budget - 78,670 Btu/Sq.Ft. (GSA Target: 75,000)
- Raw source energy budget - 202,500 Btu/Sq.Ft. (GSA Target: 150,000)
- Domestic water use - 26 gal/day/person
- Office lighting use per building area - 2.3 watts/sq.ft.
- Office supply air changes per hour - 8.0
- Building gross area per ton A/C - 614 Sq.Ft./Ton
- Overall condition of existing energy consuming equipment - Very good, normal 10 yr. obsolescence
- Specific problem areas

Highlights of Existing Conditions

o Note that the overall energy consumption of the building in terms of boundary energy was found to be close to the GSA target. The study focus then shifted to raw source reductions.

Slide 8

IDENTIFICATION AND ANALYSIS OF ENERGY CONSERVATION OPPORTUNITIES

- Reference used: Energy Conservation for Existing Buildings
- Field observations to determine project technical feasibility
- Establishment of baseline costs
- 38 conservation concepts evaluated
- LCC analysis
  - Construction costs
  - Design costs
  - Personnel costs
  - Energy costs
  - Maintenance costs
  - Replacement costs
  - Expected life
  - Other impacts
    - On other building systems
    - On health & safety
    - On building aesthetics

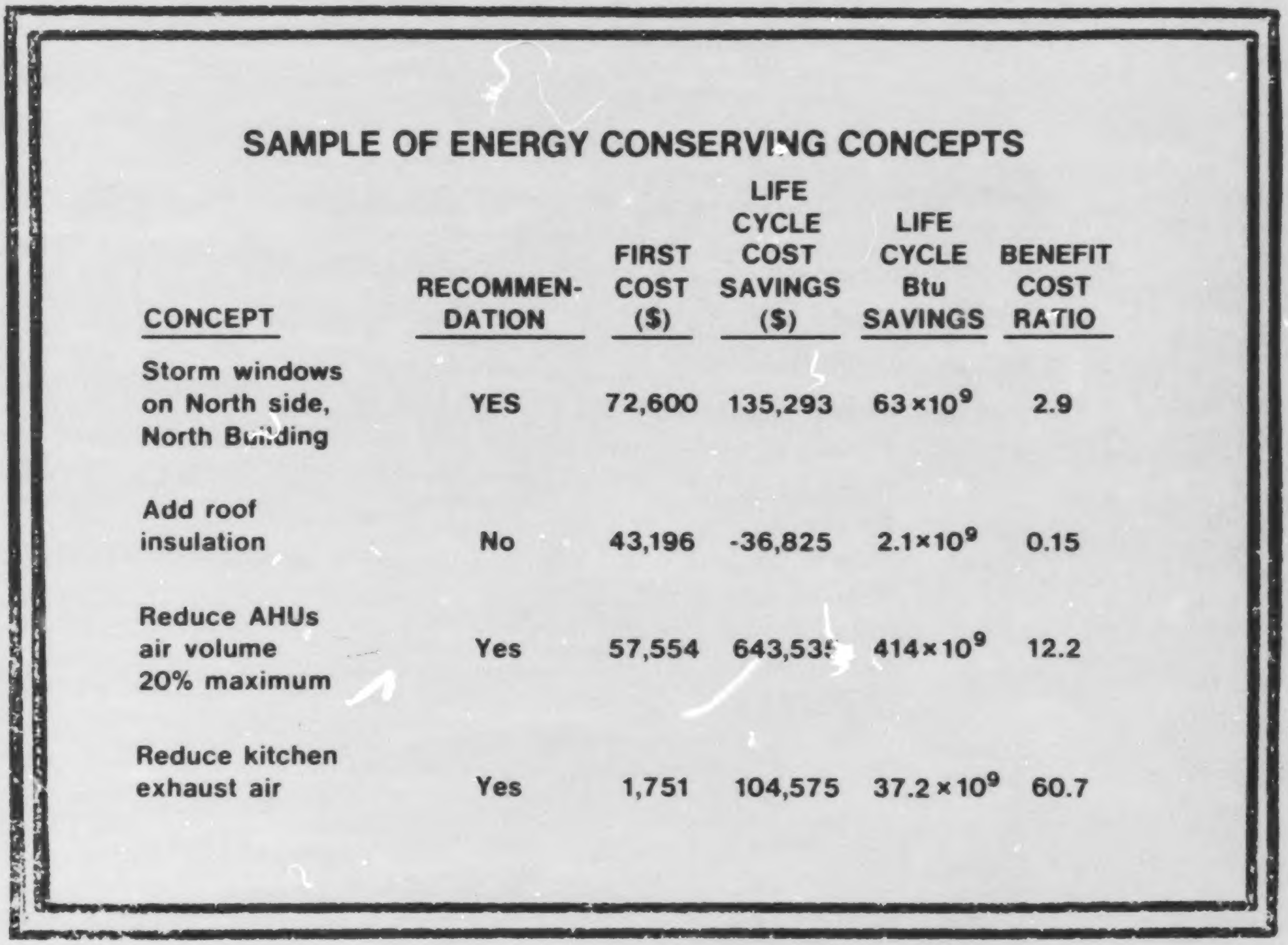
Identification and Analysis of Energy Conservation Opportunities

o The evaluation team used the list of options in the GSA publication Energy Conservation for Existing Buildings as a reference in identifying opportunities.

o Forecasts were made of present and future costs of maintaining, operating, and replacing major systems under existing conditions to provide a cost baseline against which to compare retrofit projects.

o 38 potential projects were evaluated, taking into account the factors listed on the slide.

Slide 9



SAMPLE OF ENERGY CONSERVING CONCEPTS

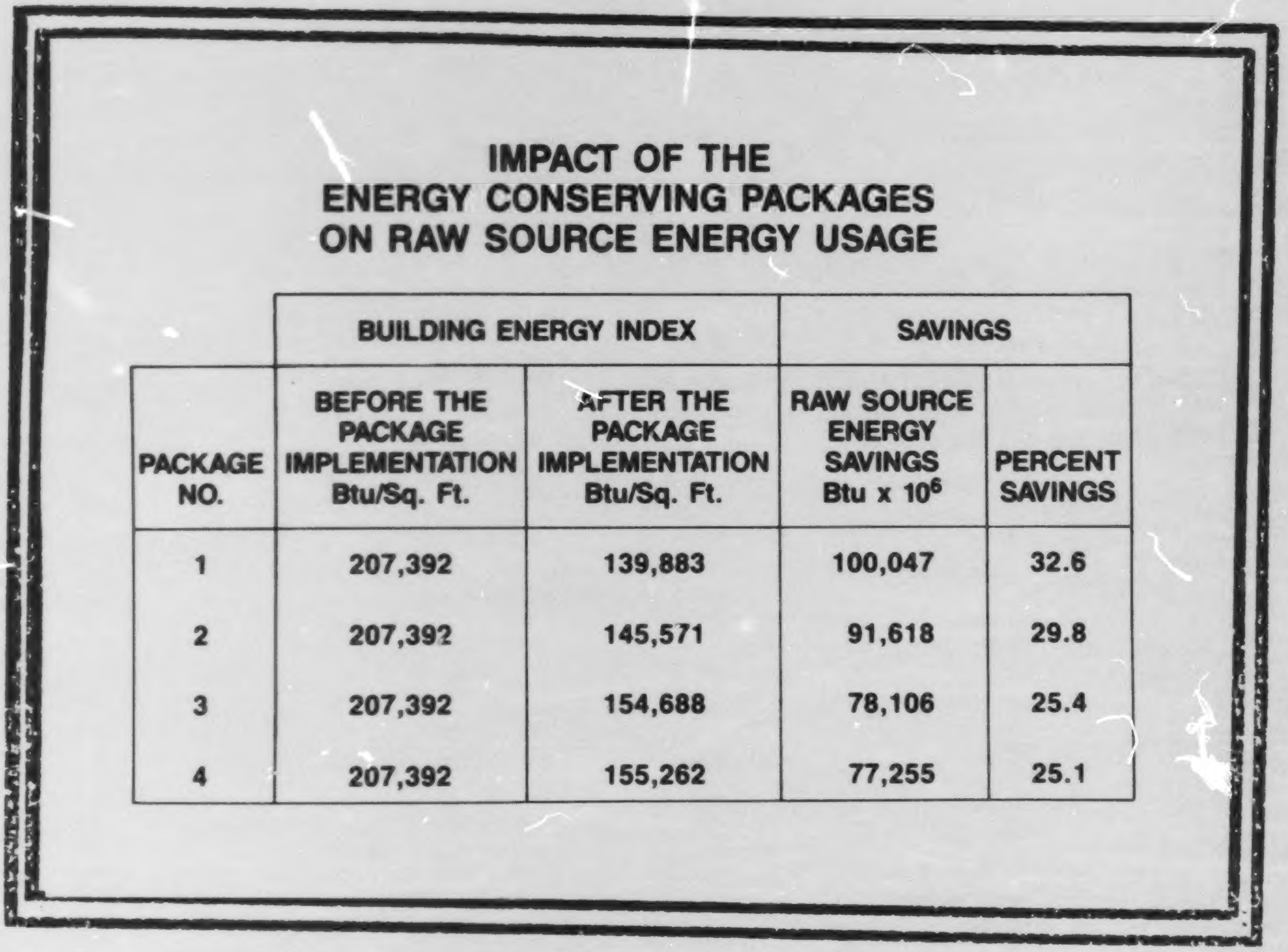
CONCEPT	RECOMMEN-DATION	FIRST COST ($)	LIFE CYCLE COST SAVINGS ($)	LIFE CYCLE Btu SAVINGS	BENEFIT COST RATIO
Storm windows on North side, North Building	YES	72,600	135,293	63×10^9	2.9
Add roof insulation	No	43,196	-36,825	2.1×10^9	0.15
Reduce AHUs air volume 20% maximum	Yes	57,554	643,535	414×10^9	12.2
Reduce kitchen exhaust air	Yes	1,751	104,575	37.2×10^9	60.7

Sample of Energy Conserving Concepts

o Point out usefulness of this type of information for decision making.

o Note that each row item is backed up in the report by fuller project descriptions and analyses.

Slide 10



IMPACT OF THE ENERGY CONSERVING PACKAGES ON RAW SOURCE ENERGY USAGE

	BUILDING ENERGY INDEX		SAVINGS	
PACKAGE NO.	BEFORE THE PACKAGE IMPLEMENTATION Btu/Sq. Ft.	AFTER THE PACKAGE IMPLEMENTATION Btu/Sq. Ft.	RAW SOURCE ENERGY SAVINGS Btu x 10^6	PERCENT SAVINGS
1	207,392	139,883	100,047	32.6
2	207,392	145,571	91,618	29.8
3	207,392	154,688	78,106	25.4
4	207,392	155,262	77,255	25.1

Impact of the Energy Conserving Packages on Raw Source Energy Usage

- The next step was to identify alternative "packages" of projects, each of which could accomplish the energy conservation goal.

- The "packages" of projects took into account project interdependencies.

Slide 1

PACKAGE SUMMARY
ENERGY CONSERVATION RETROFIT ANALYSIS FOR A FEDERAL BUILDING

PACKAGE NUMBER	FIRST COST	LC COST SAVINGS	BCR
	Dollars	Dollars	
1	405,610	6,078,478	16.0
2	476,110	5,474,408	12.5
3	126,710	5,165,592	41.8
4	191,932	5,269,167	28.5

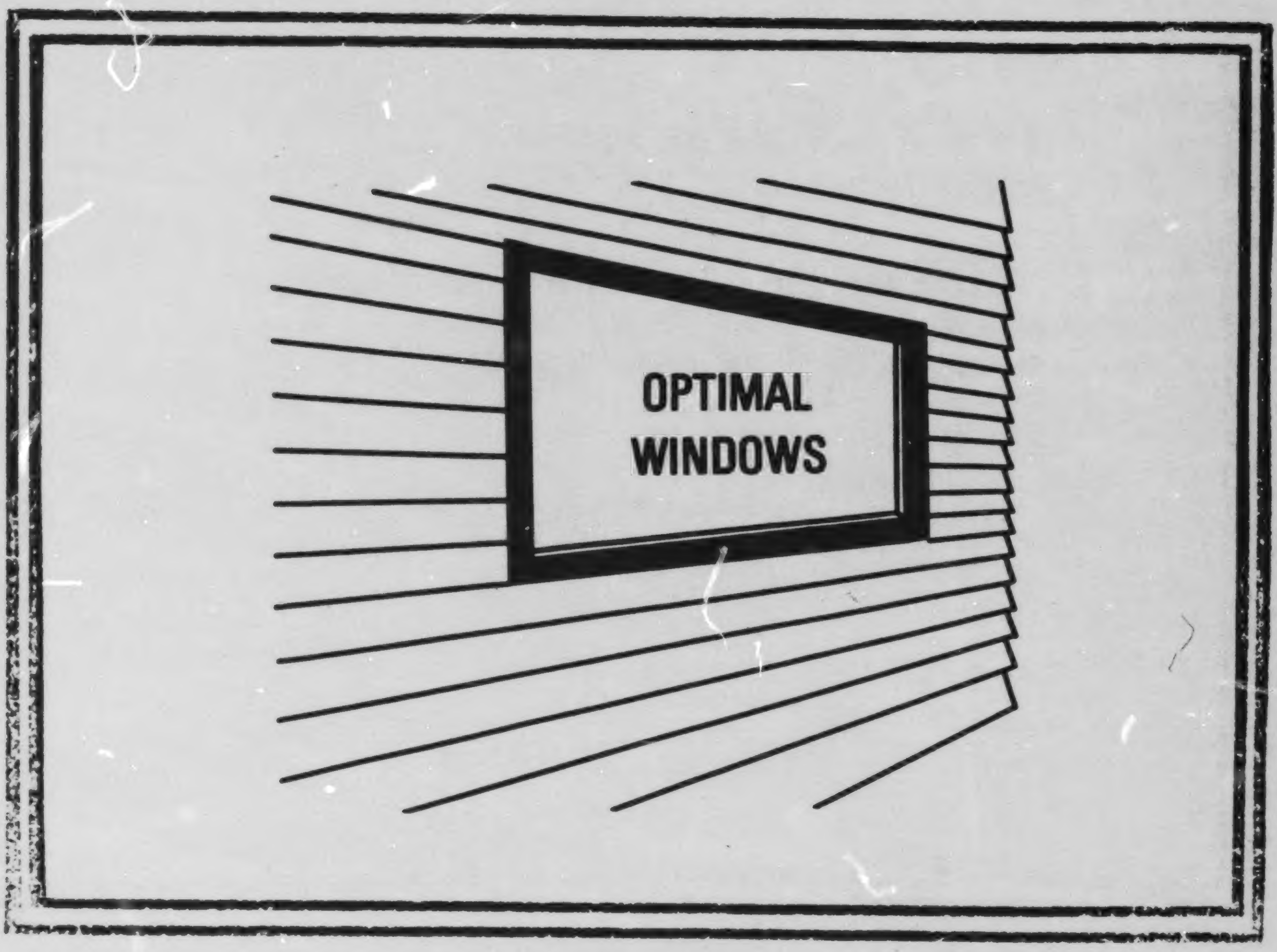
Package Summary--Energy Conservation Retrofit Analysis for a Federal Building

- The final step was to compare the cost effectiveness of the programmatically feasible packages and identify the one with the highest BCR.

- Note that none of the projects included in any of the proposed packages had BCR's < 1.

- Package #3 was recommended, with a BCR of 41.8. (Note that this package also had the highest Btu/$ index, but explain that the rankings of the Btu/$ and BCR indices will not always be compatible, as will be shown in a later session.)

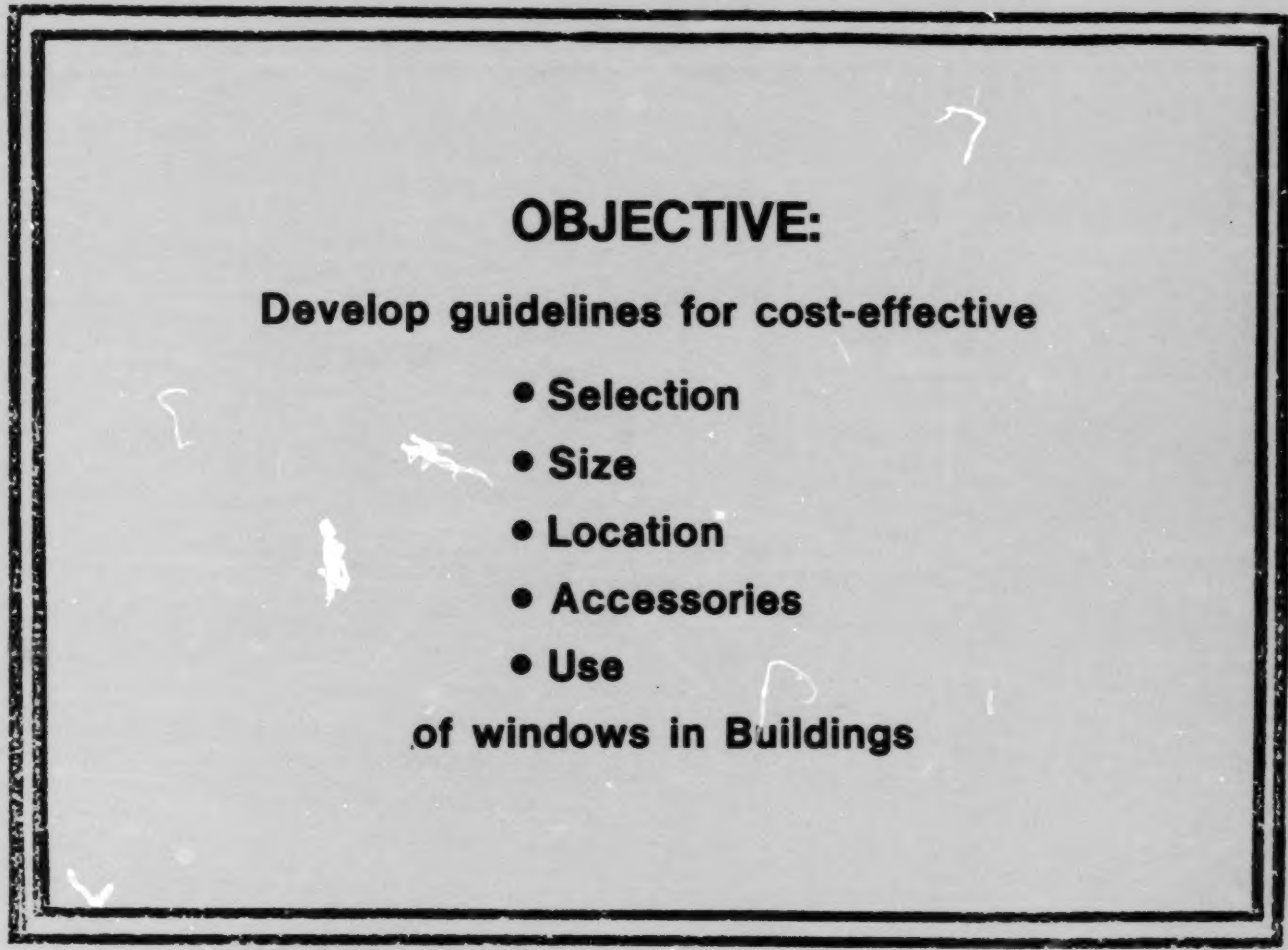
Slide 12


OPTIMAL WINDOWS

Optimal Windows

- Note that this is a generic-type study.
- Give background--Study was performed in conjunction with the Federal program to develop building energy performance standards, and at a time when some were urging a categorical reduction of window area in buildings, and others were making claims of the thermal benefits of south-facing windows apart from the use of special passive solar devices to store the heat, and apart from the use of insulation and shading.
- Cite 2 reports as source--NBS BSS 119 and NBSIR 81-2248. (Review these reports for further background information.)
- Note the multidisciplinary approach--thermal engineer, architect, and economist.

Slide 13



OBJECTIVE:

Develop guidelines for cost-effective

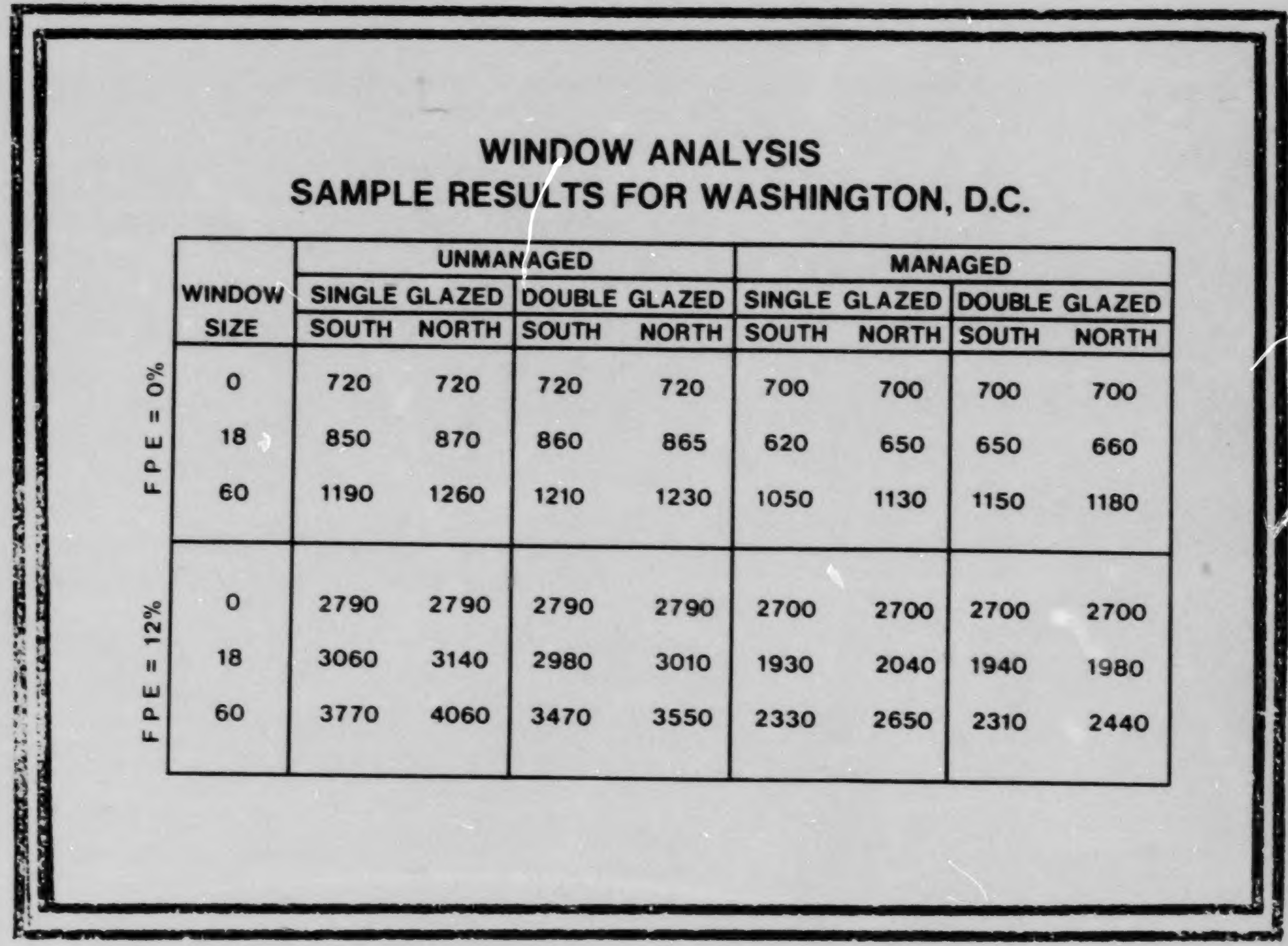
- Selection
- Size
- Location
- Accessories
- Use

of windows in Buildings

Objectives

- o Explain that the purpose was to develop general guidelines for cost-effective design, sizing, location, accessorizing, and use of windows in buildings in different regions of the country.
- o Note that the cost effectiveness of building energy investments tends to be sensitive to climatic data, i.e., what is cost effective in one part of the country may not be cost effective in another; therefore, the effect of location needs to be taken into account in developing guidelines for the country as a whole.
- o Note that there may be significant locational factors other than heating degree days and cooling hours, such as level of solar radiation and ground water temperature.

Slide 14



WINDOW ANALYSIS SAMPLE RESULTS FOR WASHINGTON, D.C.

	WINDOW SIZE	UNMANAGED				MANAGED			
		SINGLE GLAZED		DOUBLE GLAZED		SINGLE GLAZED		DOUBLE GLAZED	
		SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH	SOUTH	NORTH
FPE = 0%	0	720	720	720	720	700	700	700	700
	18	850	870	860	865	620	650	650	660
	60	1190	1260	1210	1230	1050	1130	1150	1180
FPE = 12%	0	2790	2790	2790	2790	2700	2700	2700	2700
	18	3060	3140	2980	3010	1930	2040	1940	1980
	60	3770	4060	3470	3550	2330	2650	2310	2440

Window Analysis--Sample Results for Washington, D.C.

- Explain that the economic analysis model was computerized to facilitate changing values of parameters to test the various alternatives of window selection and use.

- Point out that the table shows sample results for Washington, D.C. case studies.

- Note examples of various comparisons that can be made.

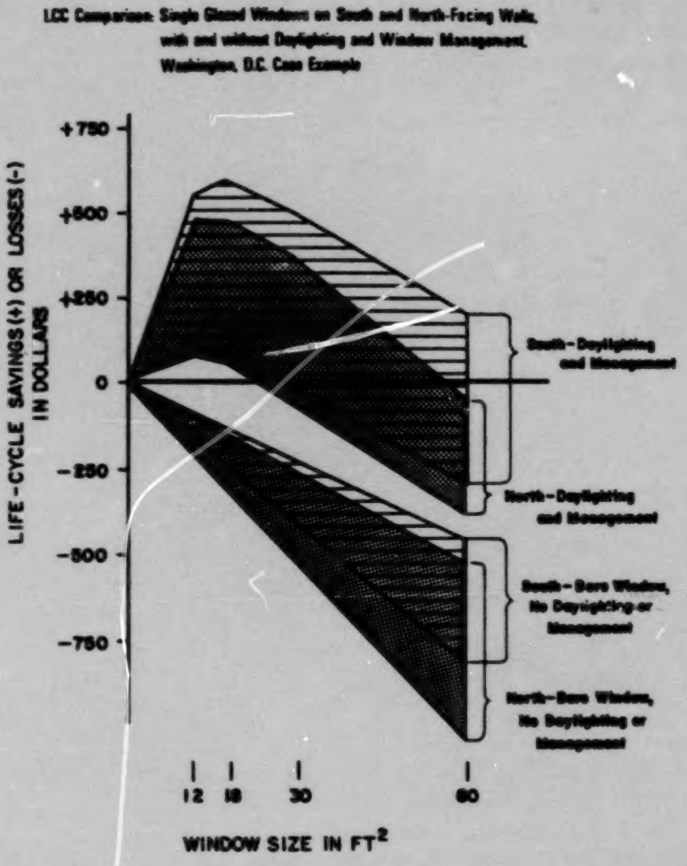
Other Possible Discussion:

- Explain the importance of identifying all of the costs and benefits that are likely to be significant to the decision.

Slide 14 (Cont.)

- o Note that some are more amenable to quantification than others.
- o Note that the analyst must decide which element to attempt to quantity in dollar terms and how to treat the other, incommensurable elements.
- o Note that as the terms are generally used, "benefit-cost" (or B-C) evaluation refers to a comparison of benefits against costs where both are variable depending on the decision that is made; while "life-cycle costing" (LCC) refers to comparing different levels of costs that are variable with the decision, where benefits remain constant. However, the distinction is often blurred, and benefits can be treated as negative costs in LCC analysis, while cost reductions can be treated as benefits in B-C analysis.

Slide 15



LCC Comparison: Single-Glazed Windows on South and North-Facing Walls, With and Without Daylighting and Window Management, Washington, D.C. Case Example

- Note that a visual display of findings is often an aid to interpretation.

Slide 15 (Cont.)

- Explain "bands" in terms of sensitivity analysis. The highest point on the upper band indicates significant savings from a 12-18 ft^2 window on the south side used for daylighting and covered at night. The lowest point on the bottom band indicates large losses from a 60 ft^2 window on the north not used for daylighting and not covered at night.

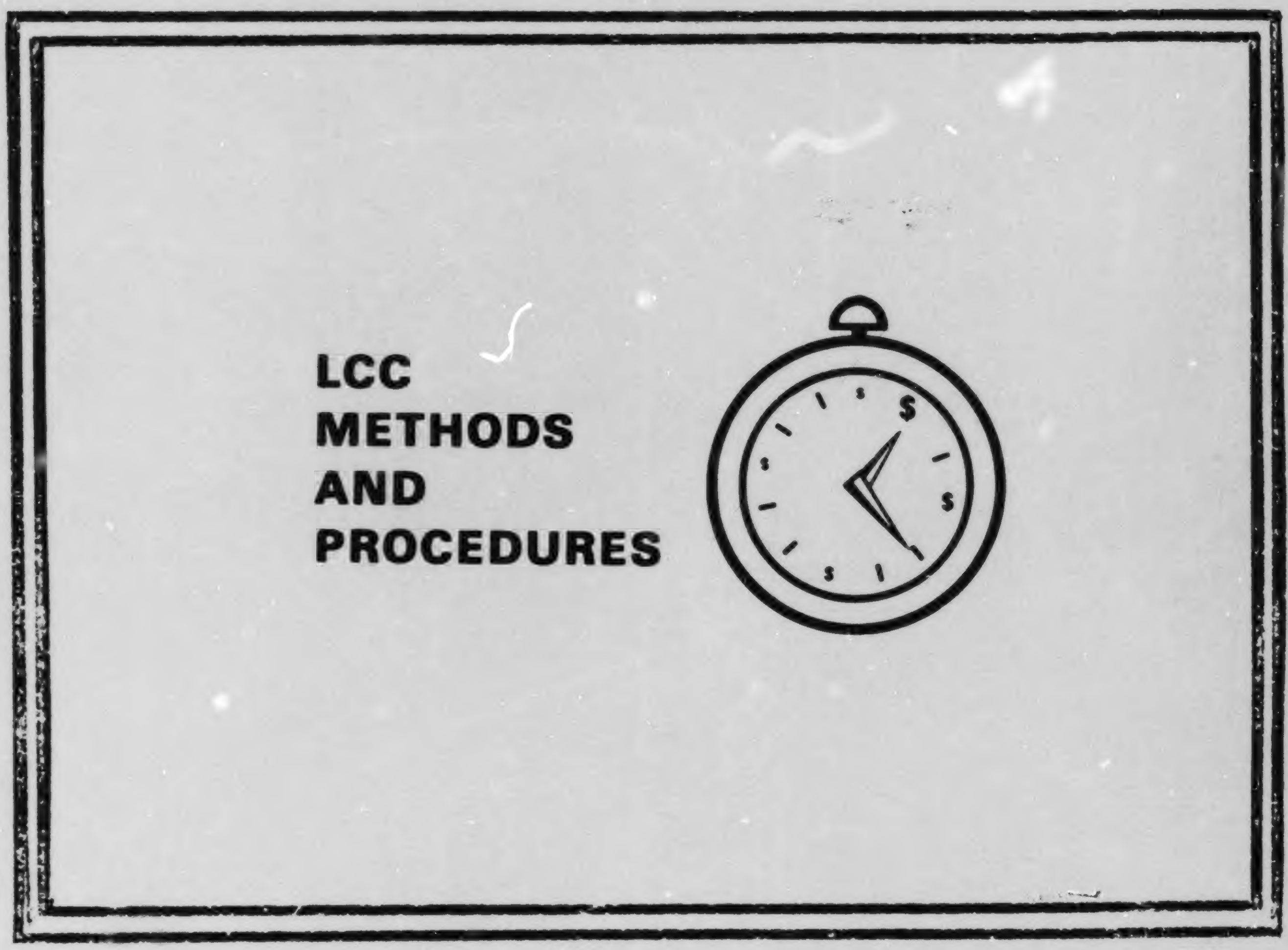
- Note possible mitigating circumstances, such as no opportunity for using daylight, view, and codes.

Section 4

Slide Presentation: Fundamentals of Benefit-Cost and LCC Analysis

The purposes of this session are to (1) describe the general characteristics of Benefit-Cost and Life-Cycle Cost Analyses, (2) to explain the steps in an economic analysis, (3) to explain in detail the discounting procedure, (4) and to illustrate discounting with sample problems.

Slide 1

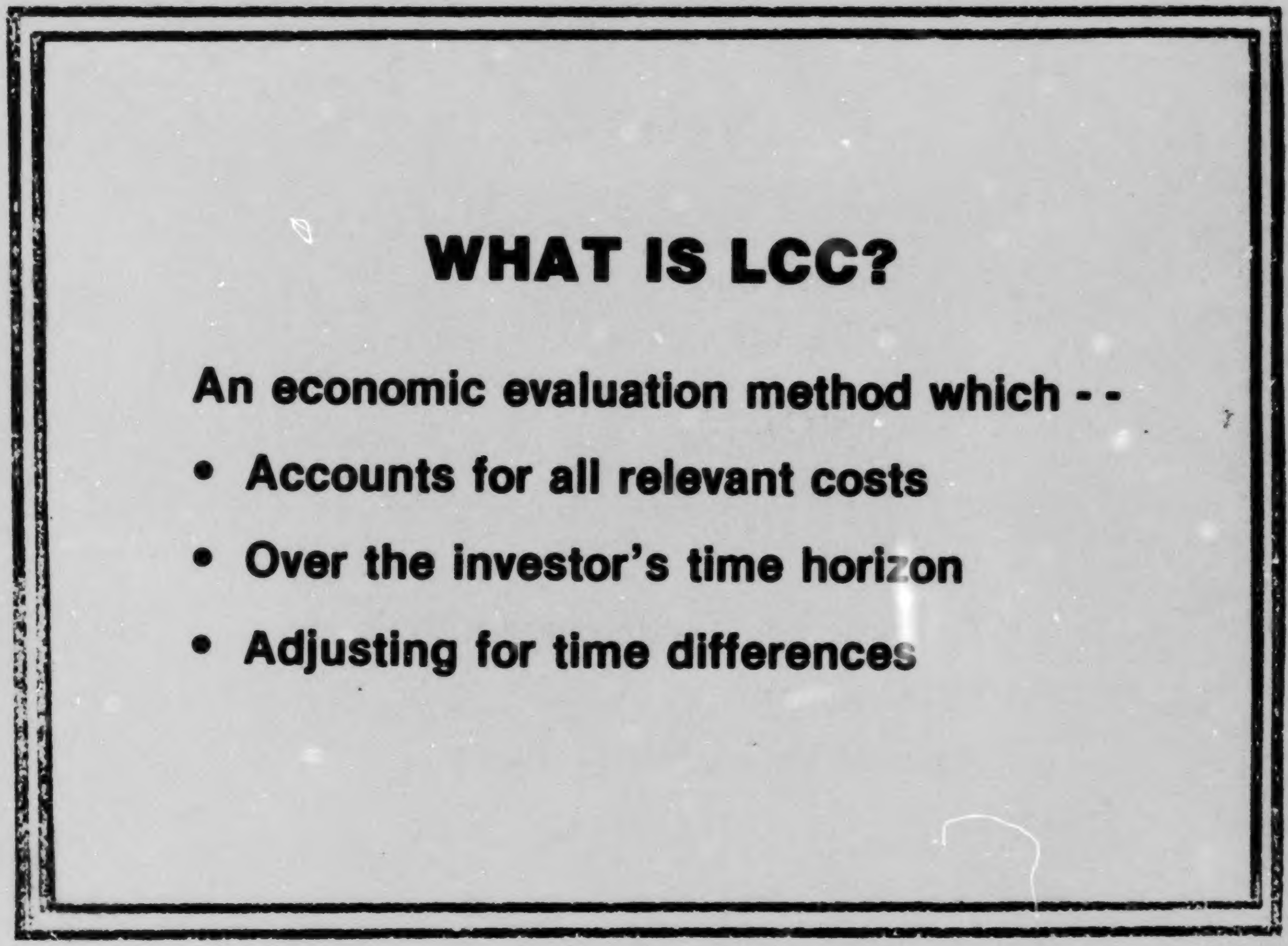


LCC
METHODS
AND
PROCEDURES

LCC Methods and Procedures

- Describe the purpose of the session.

Slide 2



WHAT IS LCC?

An economic evaluation method which - -

- Accounts for all relevant costs
- Over the investor's time horizon
- Adjusting for time differences

What Is LCC

- o Define LCC in terms of the listed characteristics.
- o Note that LCC here is a generic term that refers to a large set of economic evaluation techniques including Benefit-Cost and Savings-to-Investment Ratio analyses.

Slide 3

RELEVANT COSTS

- Investment
  - Planning
  - Design
  - Engineering
  - Purchase
  - Installation
- Energy
- Operation & Maintenance Non-Energy
- Replacement
- Salvage Value, Net of Disposal

Relevant Costs

- Explain that listed items contain most costs that might typically be found relevant.

- Note that costs are relevant if they are changed by the investment and the change is significant in amount.

Slide 4

NON-RELEVANT COSTS

- Trivial in Amount
- Do Not Affect the Decision
  - Sunk
  - Unchanged

Non-Relevant Costs

- o Describe characteristics of non-relevant costs.
- o Explain that in making a LCC evaluation only the relevant costs need be considered.

Slide 5

TIME VALUE OF MONEY

- Inflation

- Real Opportunity Cost of Capital

Time Value of Money

- Explain that a given absolute dollar sum of money has different values over time due to inflation and the real opportunity cost of capital.

- Inflation is a rise in the general price level reflecting a decline in the purchasing power of the unit of currency.

- The real opportunity cost of capital (money) is the real rate of return available on the next best investment.

- Use a savings account example to show that $1000 today is time equivalent to $1100 received one year from today when the market rate of interest is 10% per annum. Explain how that market rate of interest the bank pays the saver incorporates a return both for lending the real earning potential of the capital and for compensating inflation's erosion of the purchasing power of the principal. Note further that values occurring at different points in time cannot be simply added due to the time value of money.

Slide 6

How Can LCC Increase Savings?

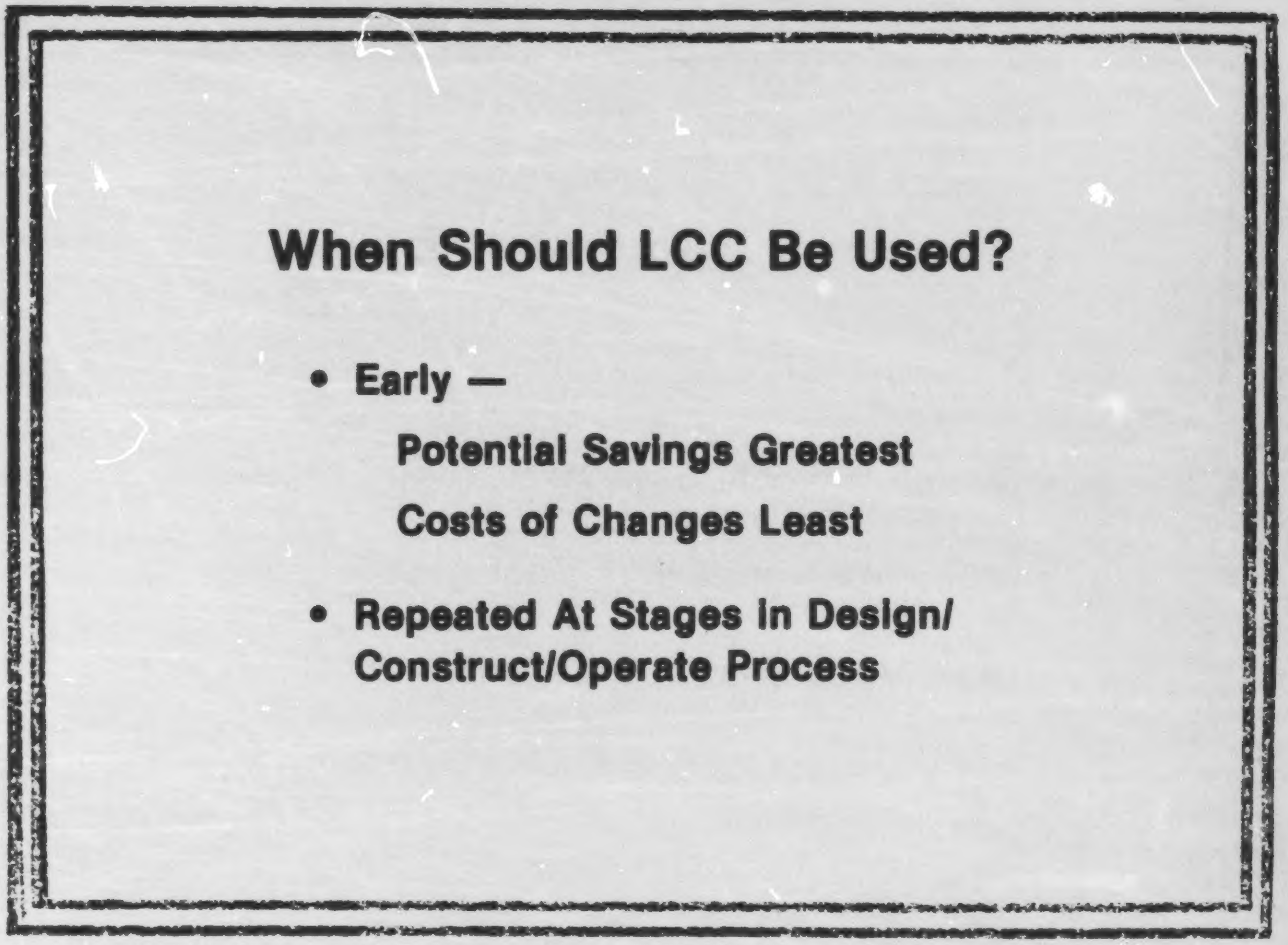
By Showing:

- **Which Projects Save More Than They Cost**
- **Which Design/Size Is Most Cost Effective**
- **How Much Should Be Spent on Each Project**
- **Which Projects Should Receive Priority**

How Can LCC Increase Savings

o Discuss each of the four situations in which LCC analysis can increase savings, and give examples.

Slide 7



When Should LCC Be Used?

- Early —

  Potential Savings Greatest

  Costs of Changes Least

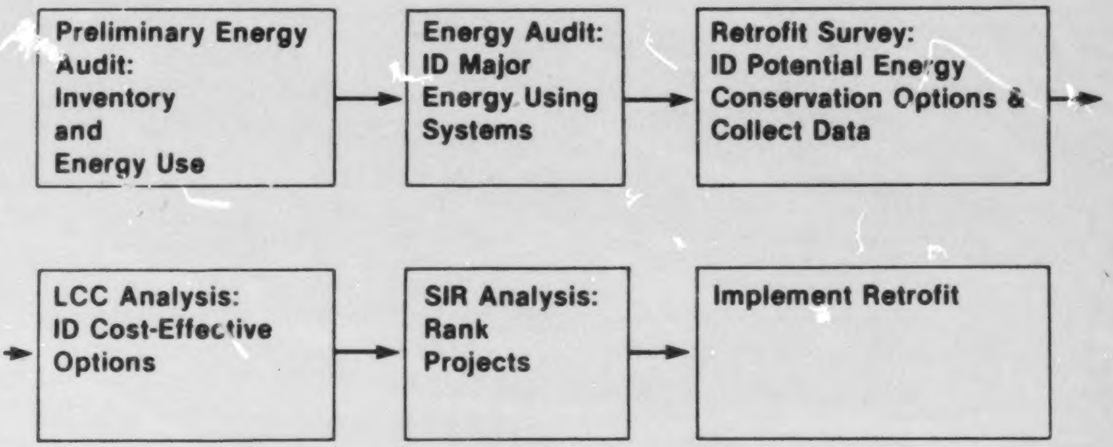
- Repeated At Stages In Design/ Construct/Operate Process

When Should LCC Be Used

o Describe under what circumstances LCC analysis is appropriate and elaborate with examples.

Slide 8

Where Does LCC Fit Into An Audit/Retrofit Program?



Preliminary Energy Audit:
Inventory
and
Energy Use

Energy Audit:
ID Major
Energy Using
Systems

Retrofit Survey:
ID Potential Energy
Conservation Options &
Collect Data

LCC Analysis:
ID Cost-Effective
Options

SIR Analysis:
Rank
Projects

Implement Retrofit

Audit/Retrofit Program

- Proceed step-by-step through the flow chart of activities in explaining how LCC fits into an audit/retrofit program.

Slide 9

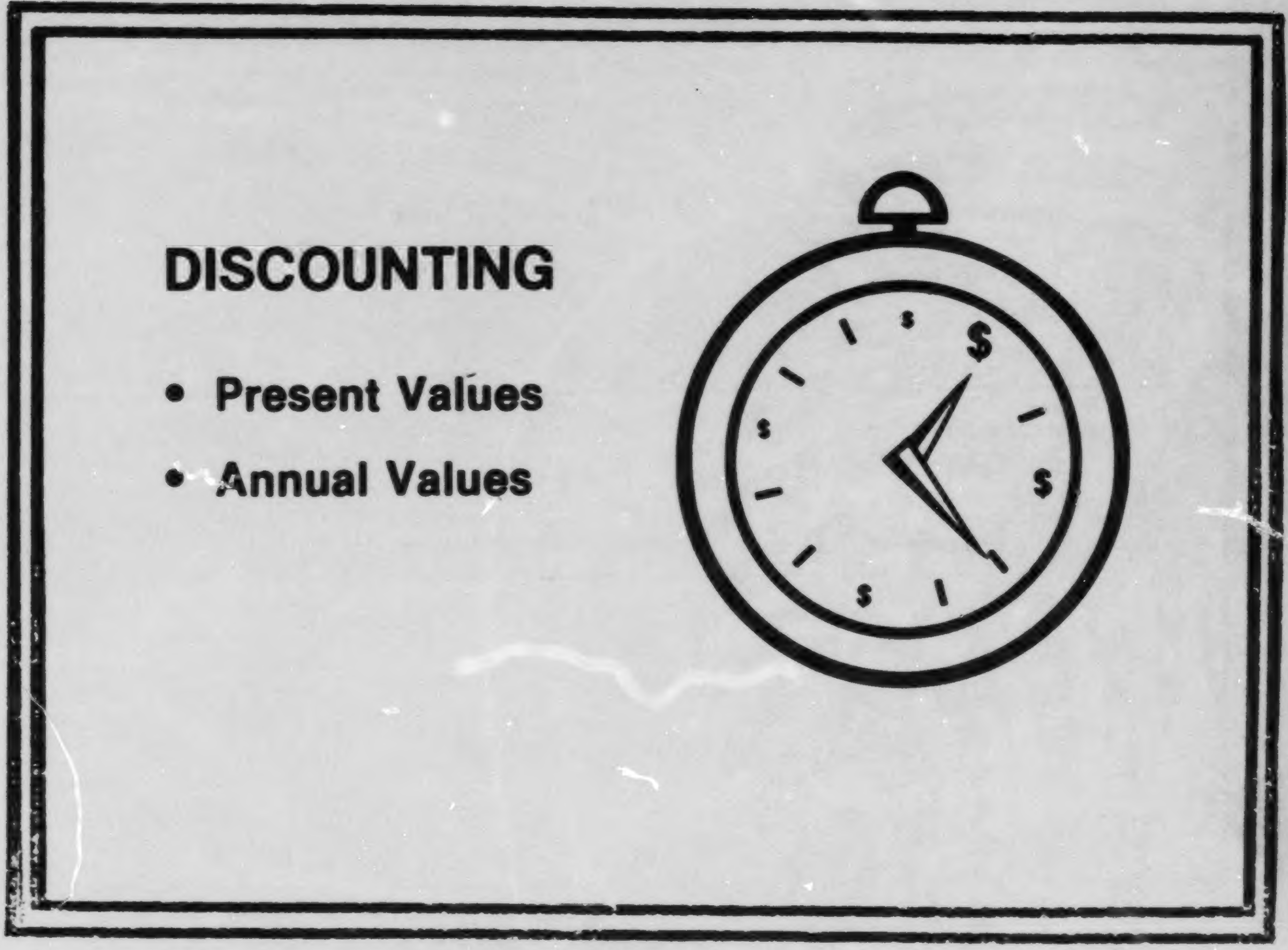
STEPS IN LCC EVALUATION

- Identify Objectives
- Identify Constraints
- Identify Choices
- Estimate Relevant Costs and Savings
- Adjust Costs and Savings For Time Differences
- Calculate Measures of Economic Performance
- Compare Alternatives
- Perform Sensitivity Analysis

Steps in LCC Evaluation

o Explain each step and elaborate on each with an example. Evaluating a heating/cooling system for a building is a good case illustration.

Slide 10



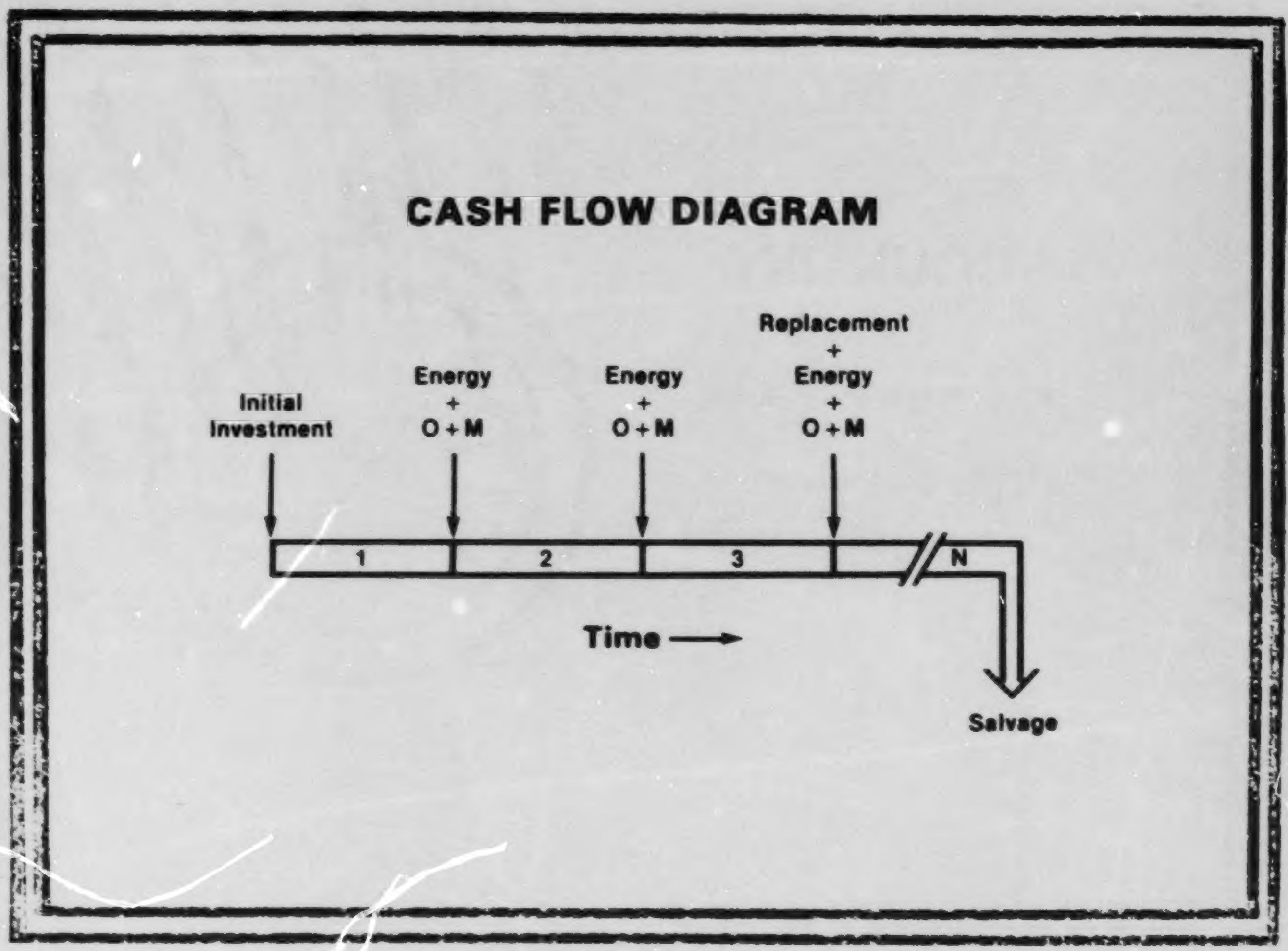
DISCOUNTING

- Present Values
- Annual Values

Discounting

- o Explain that all of the LCC techniques require discounting to put benefit (saving) and cost figures in time equivalent values. The purpose of the following slides is to (1) define discounting, discount rates, discount formulas, and discount factors; explain the discounting procedures; and to show the impact of discounting with different rates.
- o Define discounting as a method of time adjustment that puts cash flows on a time equivalent basis.
- o Define present value as the value of benefits or costs found by discounting future or annual cash flows to the present time.
- o Define annual value as a uniform annual amount over a specified period equivalent to project benefits or costs at a point in time.

Slide 11



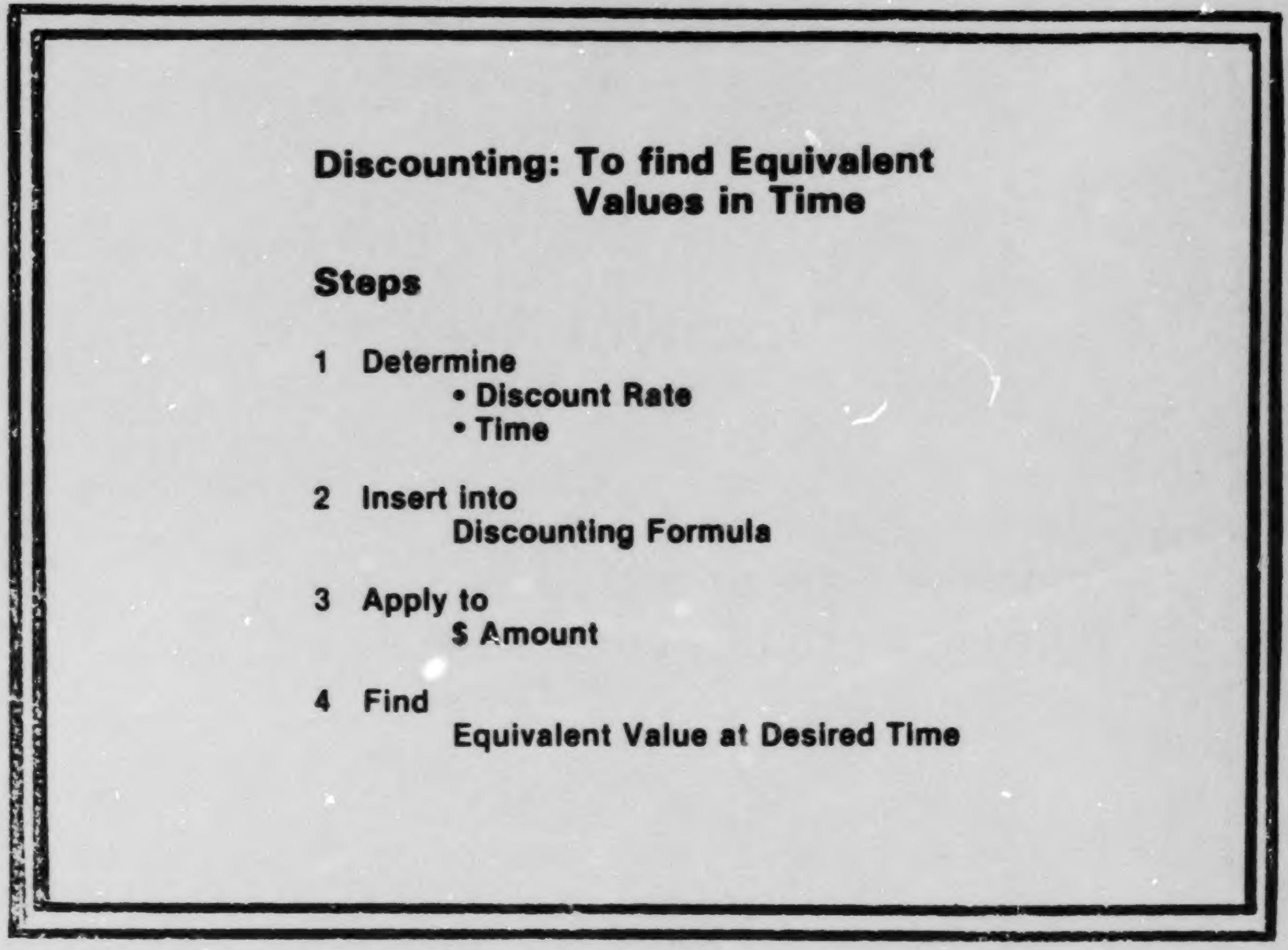
CASH FLOW DIAGRAM

Initial Investment
Energy + O + M
Energy + O + M
Replacement + Energy + O + M
1
2
3
N
Time ⟶
Salvage

Cash Flow Diagram

- o Explain the diagram.
- o Describe how it can be used to structure a discounting problem and choose the appropriate discounting formula.

Slide 12



Discounting: To find Equivalent Values in Time

Steps

1 Determine
- Discount Rate
- Time

2 Insert into
Discounting Formula

3 Apply to
$ Amount

4 Find
Equivalent Value at Desired Time

Discounting: To Find Equivalent Values in Time

- Describe the steps in discounting.

Slide 13

Discount Rate

The Discount Rate is a rate of interest used to convert savings and costs occurring at different times to a common time.

Discount Rate

- Define the discount rate.

Discount Rates

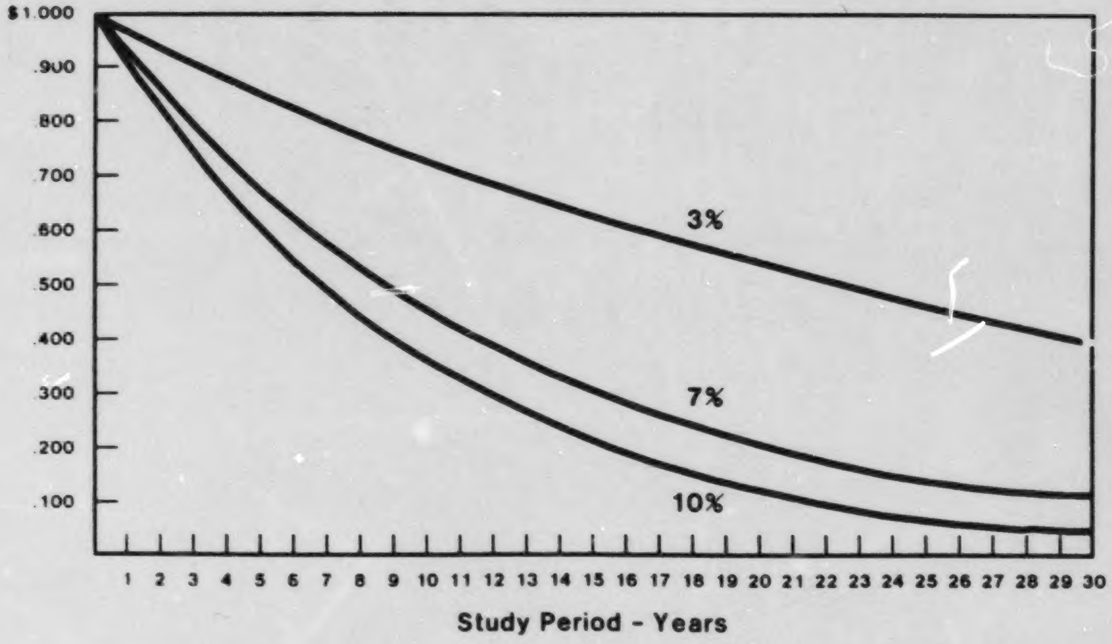
- Nominal (Market) vs. Real
- Determining the Value of
- Examples
- Impact

Discount Rates

- o Distinguish nominal from real rates.
- o Discuss the determination of the rate.
- o Explain that the rate for FEMP is 7% real.
- o Note that OMB Circular A-94 requires 10% for most non-energy conservation evaluations, aside from water project evaluations.
- o Explain the impact on net benefits of high and low discount rates.

Slide 15

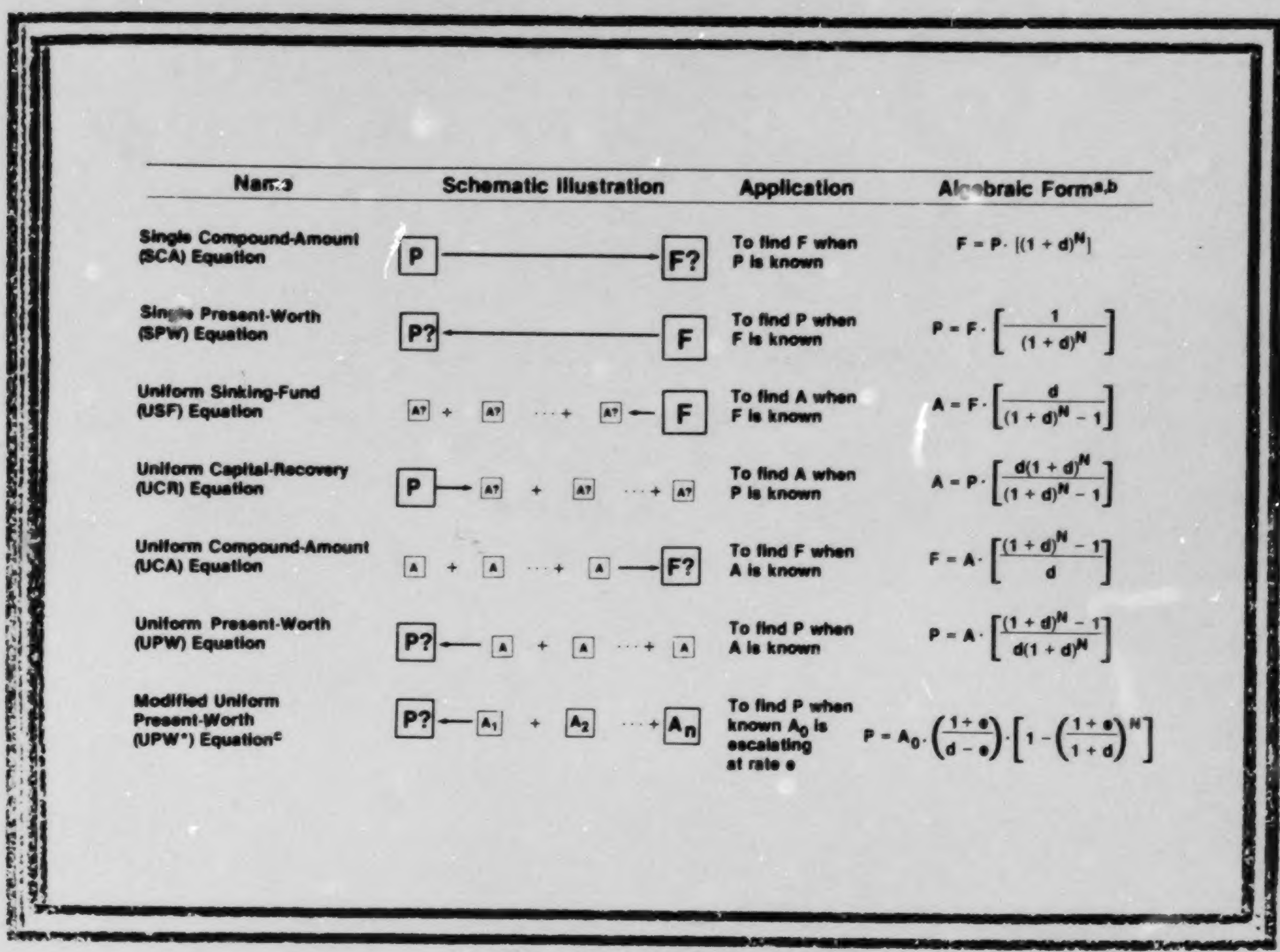
Discounting: Comparison of Rates



Discounting: Comparison of Rates

- Show how, for a given discount rate, the value of a dollar received farther and farther in the future becomes worth less and less in purchasing power of today's dollar.
- Show how the present value of a dollar received in any given future year will be worth less in today's dollar terms for higher rates than for lower rates.
- Explain the implications of different discount rates for energy conservation programs.

Slide 16



Name	Schematic Illustration	Application	Algebraic Form^{a,b}
Single Compound-Amount (SCA) Equation	$\boxed{P} \longrightarrow \boxed{F?}$	To find F when P is known	$F = P \cdot [(1+d)^N]$
Single Present-Worth (SPW) Equation	$\boxed{P?} \longleftarrow \boxed{F}$	To find P when F is known	$P = F \cdot \left[\frac{1}{(1+d)^N}\right]$
Uniform Sinking-Fund (USF) Equation	$\boxed{A?} + \boxed{A?} \cdots + \boxed{A?} \longleftarrow \boxed{F}$	To find A when F is known	$A = F \cdot \left[\frac{d}{(1+d)^N - 1}\right]$
Uniform Capital-Recovery (UCR) Equation	$\boxed{P} \longrightarrow \boxed{A?} + \boxed{A?} \cdots + \boxed{A?}$	To find A when P is known	$A = P \cdot \left[\frac{d(1+d)^N}{(1+d)^N - 1}\right]$
Uniform Compound-Amount (UCA) Equation	$\boxed{A} + \boxed{A} \cdots + \boxed{A} \longrightarrow \boxed{F?}$	To find F when A is known	$F = A \cdot \left[\frac{(1+d)^N - 1}{d}\right]$
Uniform Present-Worth (UPW) Equation	$\boxed{P?} \longleftarrow \boxed{A} + \boxed{A} \cdots + \boxed{A}$	To find P when A is known	$P = A \cdot \left[\frac{(1+d)^N - 1}{d(1+d)^N}\right]$
Modified Uniform Present-Worth (UPW*) Equation^c	$\boxed{P?} \longleftarrow \boxed{A_1} + \boxed{A_2} \cdots + \boxed{A_n}$	To find P when known A_0 is escalating at rate e	$P = A_0 \cdot \left(\frac{1+e}{d-e}\right) \cdot \left[1 - \left(\frac{1+e}{1+d}\right)^N\right]$

Discount Formulas

- o Explain that this set of formulas is used to move values in time, taking into account compound interest.
- o Direct class to p. 9 of Handbook 135 and the Discounting section of the Workbook for duplicate tables of what is on the screen and to pp. 10-14 for problem illustrations of the formulas.
- o Describe each column of the table and how to find the appropriate formula for any discounting problem.
- o Explain briefly what each formula does and in what situation it is used.
- o Work an example on the board for the SCA factor before moving to the second row. The yield on a zero-coupon bond or IRA makes a good example.

Slide 17

DISCOUNTING FORMULAS

MULTIPLIER FACTORS

Discounting Formulas/Multiplier Factors

- o Encourage the use of a multiplier factor derived from the formula for convenience and speed of calculation.

- o Illustrate on the board the derivation of the SPW factor from the formula $P = F \frac{1}{(1+d)^N}$. Note that a table of values for $\frac{1}{(1+d)^N}$ is calculated for all likely combinations of d and N, and that the present value of a future value can then be calculated simply by multiplying the future value times the precalculated factor. Similar factors are derived from the discounting formulas for the other discounting operations.

- o Direct class to pp. 114-115 of HB-135 for tables of precalculated factors for a 7% discount rate.

- o Direct class to the tables in the Workbook for discount factors based on 10% and 7% discount rates.

Slide 17 (Cont.)

- Illustrate the use of the tables with "Problem Illustrations in Discounting" in the Workbook. They may be discussed selectively, but at least cover problems 1, 2, and 8, with the emphasis on the factor approach. Discuss the notation (e.g., $P = F \cdot SPW_{10yr,10\%}$) associated with the factor acronymns.

- Note that the formulas combining energy escalation and discounting in problems 7 and 8 will be discussed in detail in a subsequent presentation.

Section 5

Problems: Discounting and LCC Analysis Using Discount Factor Tables

The purpose of this session is to provide a brief review of and practice in discounting, using the discount factor tables found in the Workbook and in Handbook 135 for Federal energy conservation projects.

A total of nine short problems are presented in this session. Slides are provided for the first three problems. The first three can be worked by the instructor with class participation. (See the notes accompanying the slide copies which follow.) The next six problems are found on p. 11-2 of Workbook Section 11, "6 Problems: Discounting and LCC Analysis Using Discount Factor Tables." This set of problems can be assigned for class solution and worked by the instructor on the blackboard or flip chart. (See notes in this session under heading, "Problems Worked on Blackboard or Flip Chart.") Solution slides are provided for the last of the "6 Problems."

Slide 1

Problem: What is maximum amount that is economical to spend today in order to avoid a replacement cost in the future?

- Replacement Cost: $10,000 (Constant $)
- Replacement in 6 Years
- Discount Rate: 7%

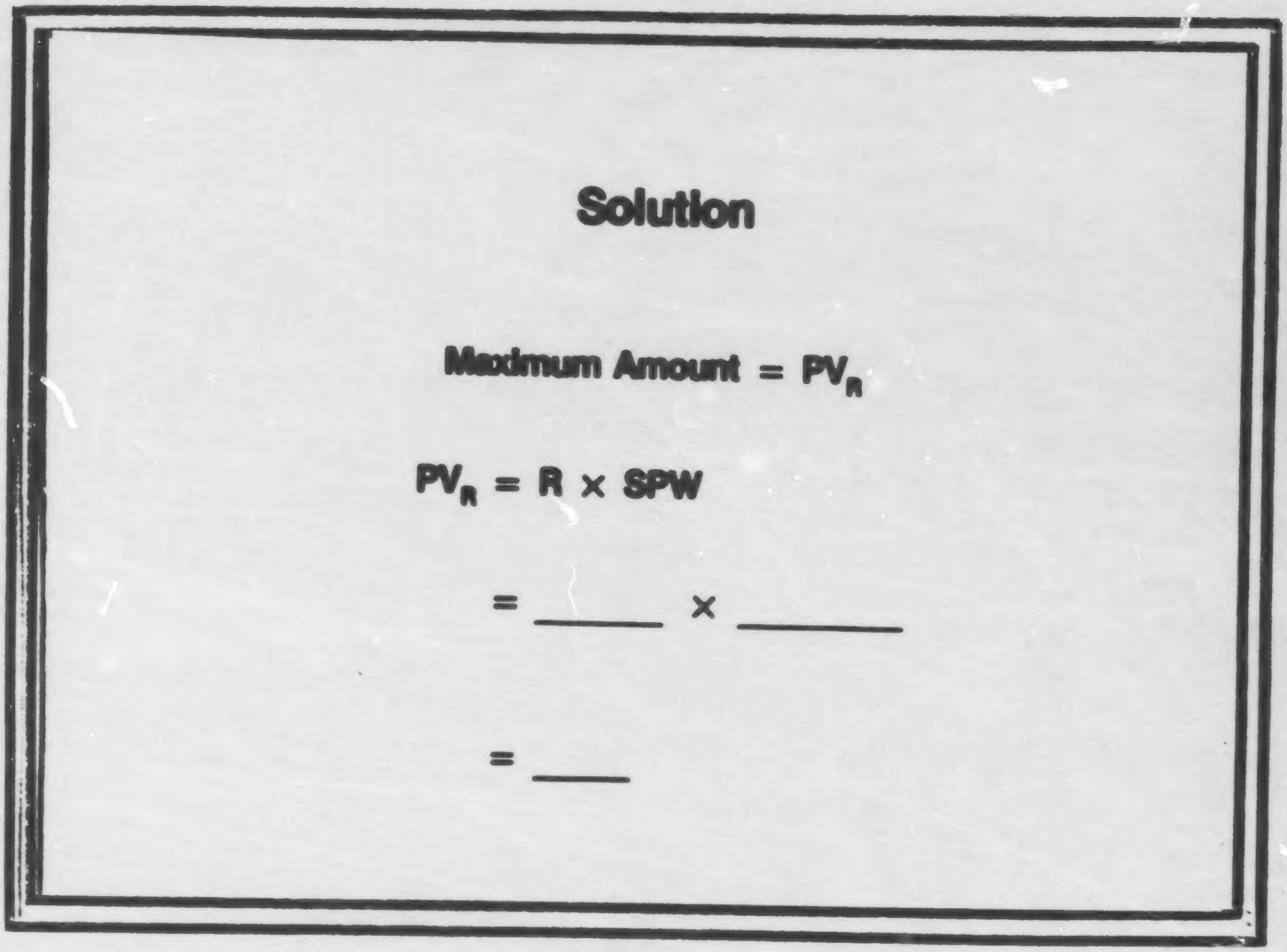
Problem: What is Maximum Amount that is Economical to Spend Today in Order to Avoid a Replacement Cost in the Future?

o Note that this is like the future cost problem presented in the preceding lecture on discounting, except that it is worked in a way more characteristic of an actual problem.

o Note the assumptions.

o Ask how the question can be answered.

Slide 2



Solution

$$\text{Maximum Amount} = PV_R$$

$$PV_R = R \times SPW$$

$$= \_\_\_\_\_\_ \times \_\_\_\_\_\_\_$$

$$= \_\_\_\_$$

Solution

- Explain that the question can be answered by solving for the present value of replacement cost.

- Go through the calculation procedure, asking for values to insert in the equation.

Slide 3

Solution

$$\text{Maximum Amount} = PV_R$$

$$PV_R = R \times SPW$$

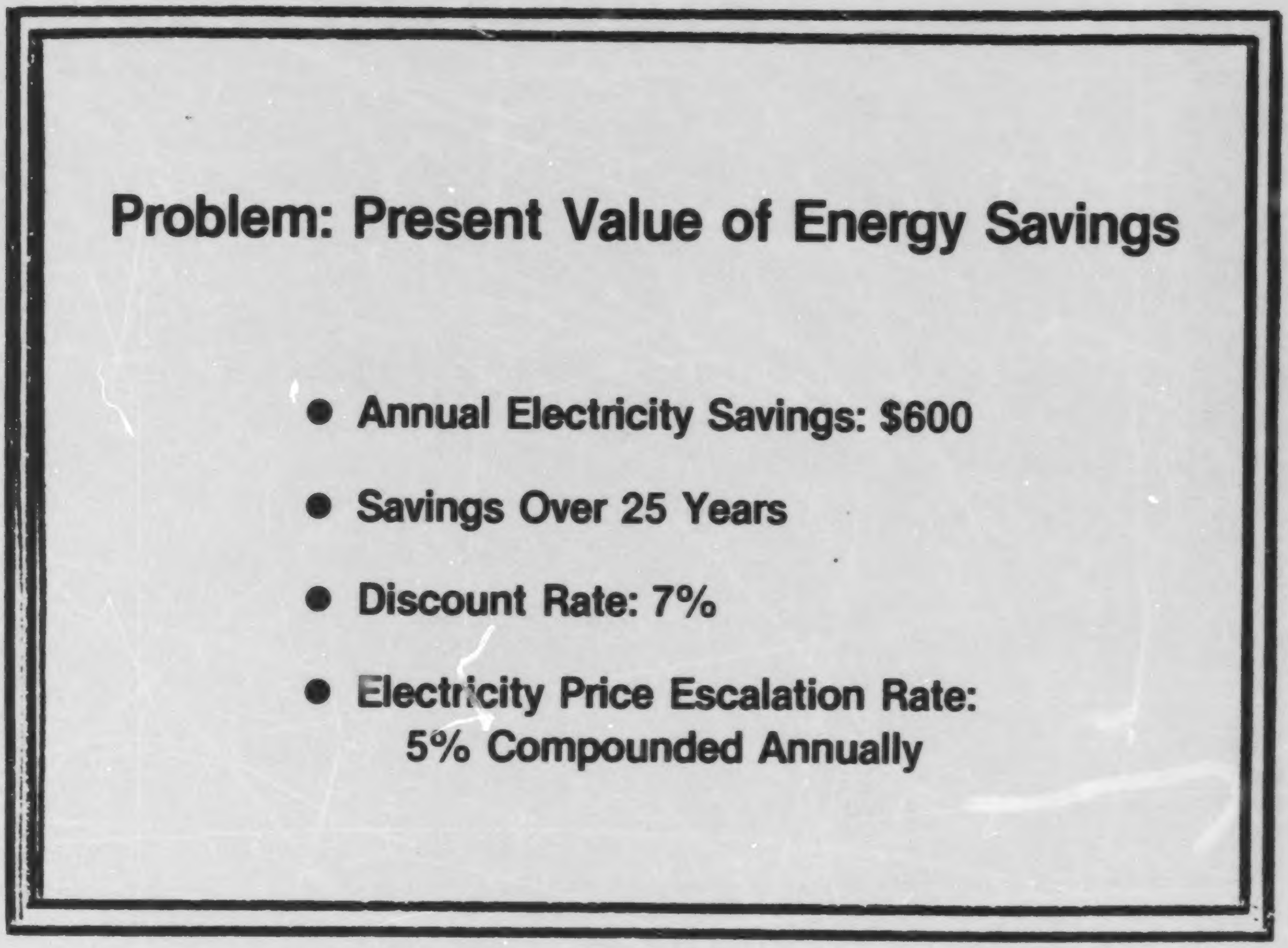
$$= \underline{\$10{,}000} \times \underset{\text{(Table A-1)}}{\underline{0.67}}$$

$$= \underline{\$6700}$$

Solution

- Go through the solution.
- Discuss the concept of equivalency between the present value amount and the future value amount.

Slide 4



Problem: Present Value of Energy Savings

- Annual Electricity Savings: $600
- Savings Over 25 Years
- Discount Rate: 7%
- Electricity Price Escalation Rate: 5% Compounded Annually

Problem: Present Value of Energy Savings

- o Discuss the assumptions.
- o Ask how the problem can be solved, i.e., what formula is needed.

Slide 5

Solution

$$UPW^* = \left(\frac{1+e}{i-e}\right)\left[1-\left(\frac{1+e}{1+i}\right)^N\right]$$

$$PV_{ES} = AES \times UPW^*$$

$$UPW^* = \left(\frac{1+\_}{\_-\_}\right)\left[1-\left(\frac{1+\_}{1+\_}\right)^{\_}\right] = \_\_\_$$

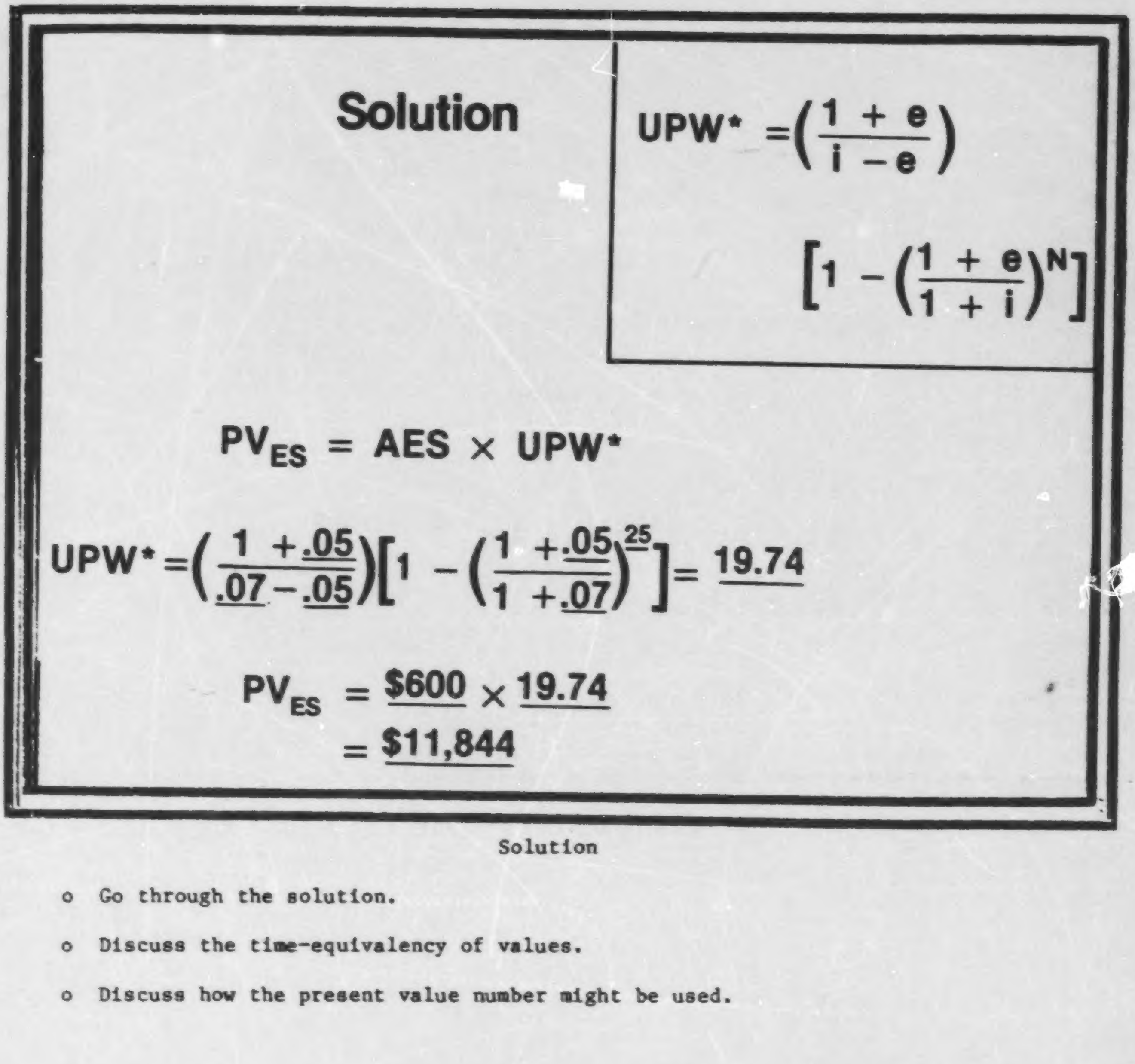
$$PV_{ES} = \_\_\_ \times \_\_\_$$

$$= \_\_\_$$

Solution

- Note the formula.
- Go through the calculation procedure, asking for values to insert in the equation.

Slide 6



Solution

$$UPW^* = \left(\frac{1+e}{i-e}\right)\left[1-\left(\frac{1+e}{1+i}\right)^N\right]$$

$$PV_{ES} = AES \times UPW^*$$

$$UPW^* = \left(\frac{1+\underline{.05}}{\underline{.07}-\underline{.05}}\right)\left[1-\left(\frac{1+\underline{.05}}{1+\underline{.07}}\right)^{25}\right] = \underline{19.74}$$

$$PV_{ES} = \underline{\$600} \times \underline{19.74}$$
$$= \underline{\$11{,}844}$$

Solution

- Go through the solution.
- Discuss the time-equivalency of values.
- Discuss how the present value number might be used.

Slide 7

Problem: LCC of Energy Savings

- Annual Electricity Savings: 100 × 10^6 Btu
- Savings Over 10 Years
- Building: Use — Offices
  Location — Los Angeles
- Discount Rate: 7%

Problem: LCC of Energy Savings

- o Discuss how the price per unit of energy is found. Explain that the Federal LCC Rule originally instructed agencies to use the DoE average regional price per unit as given in the appropriate Appendix C table of Handbook 135 as the initial price of energy, but that the revised LCC Rule directs Federal agencies to use their actual price per unit of energy as the initial price if they have it, and to use the prices from Appendix C only as default values. Point out that since no actual price was specified in the assumptions, the default value from Table C-9 of $19.84 will be used.

- o Discuss how the appropriate UPW* factor is found. (8.25 from Table B-9 of Handbook 135.)

Slide 8

Solution

$$LCC_{ES} = \text{MBtu Saved/Year} \times \text{\$/MBtu} \times \text{UPW}^{*}$$

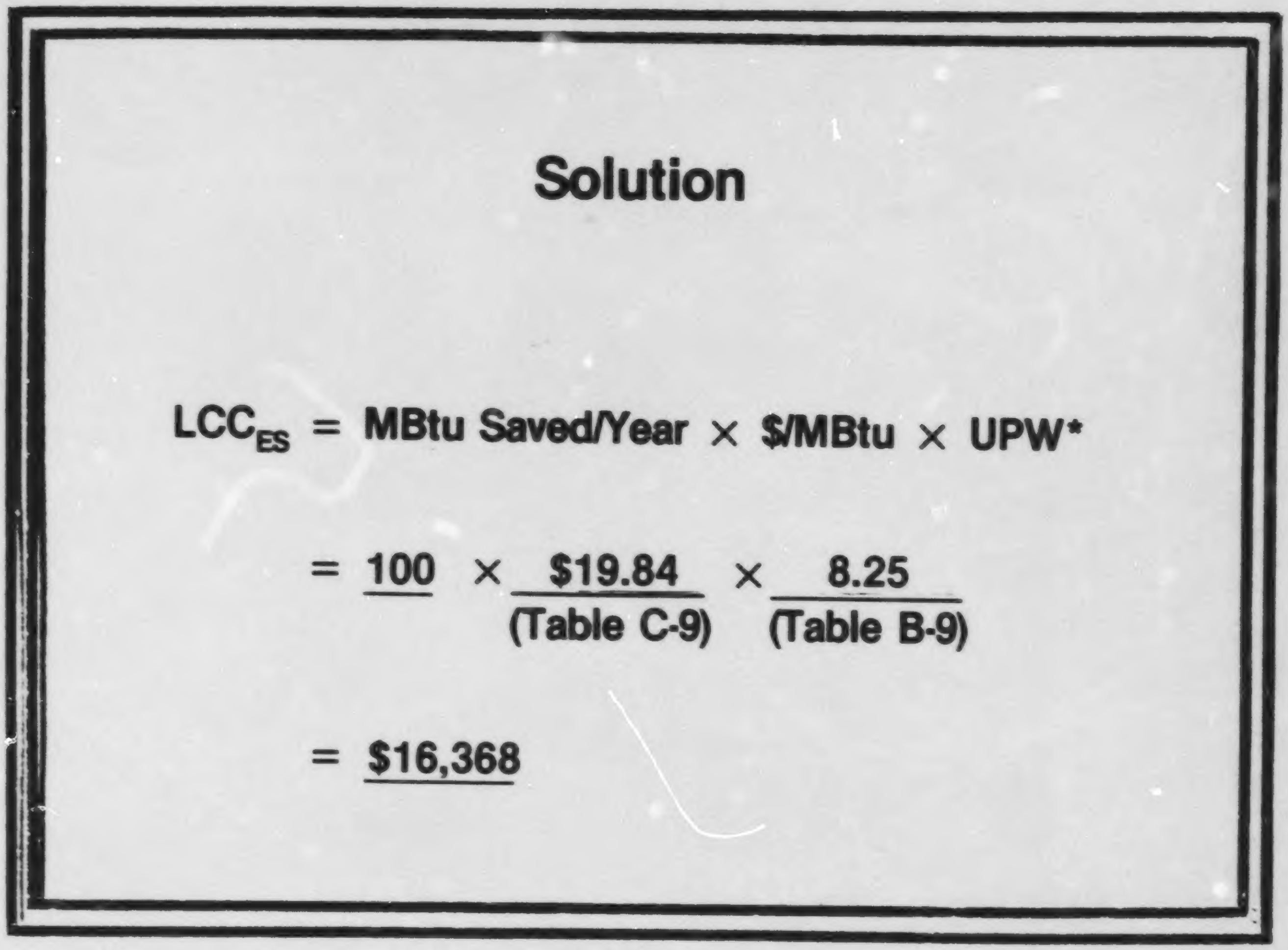
$$= \underline{\hspace{2em}} \times \underline{\hspace{6em}} \times \underline{\hspace{6em}}$$

$$= \underline{\hspace{5em}}$$

Solution

- Discuss the assumptions.
- Ask how the problem can be solved.

Slide 9



Solution

$$LCC_{ES} = \text{MBtu Saved/Year} \times \text{\$/MBtu} \times \text{UPW*}$$

$$= \underline{100} \times \underset{\text{(Table C-9)}}{\underline{\$19.84}} \times \underset{\text{(Table B-9)}}{\underline{8.25}}$$

$$= \underline{\$16{,}368}$$

Solution

- Go through the solution.
- Explain how the UPW* factor was calculated, using the formula in the footnote to the Appendix B tables and the multi-period escalation rates found in the last three columns of Table C-9. (If time allows, show the calculation of the 8.25 UPW* factor on the blackboard or flip chart while the solution slide remains on the screen.)
- If Appendix B and Appendix C tables have not yet been updated, explain how the existing UPW* factors are calculated with mid-1981 as the base year.
- Discuss how the resulting present value amount might be useful.

Problems Worked on Blackboard or Flip Chart

- Ask participants to turn to page 11-2 of Section 11 of their Workbook, "6 Problems." (Problems #1-5 are to be worked on blackboard or flip chart.)
- Allow them time to read and work a problem, ask for the answer, and then work the problem on the blackboard or flip chart.
- While they are working, diagram the cash flow on the board or chart.
- For each problem, discuss time-equivalency concept.

[The problem sheet and solutions follow.]

6 Problems: Discounting and LCC Analysis Using Discount Factor Tables

[These are hypothetical examples intended only to illustrate the techniques.]

1. What is the estimated present value today to the Federal Government of a $10,000 cost to be incurred five years from now in conjunction with an energy conservation project? What is the equivalent annual value?

2. What is the estimated present value today to the Federal Government of a uniform annual cost of $1,000 (in constant dollars) that recurs over the next 20 years? (The cost stems from a renewable energy project). What is the equivalent annual value?

3. What is the estimated present value today of electricity costs for powering a motor in a Washington, D.C. Federal office building over the next 15 years, given that today's price of electricity is 6¢ per kWh, and the annual energy consumption is 8,000 kWh? What is the equivalent annual value?

4. What is the estimated present value of a reduction of 10,000 gallons/year in distillate fuel oil consumption for heating a Federal office building in Boston, given that the current price per gallon is $1.30, and the savings are expected to continue over the remaining life of the building, estimated at 50 years? What is the equivalent annual cost?

5. What is the DoE-projected average U.S. price per cubic foot of natural gas for commercial-type use in mid-1983?

6. What is the total present value cost over its useful life of purchasing, installing, operating, maintaining, and, finally, disposing of a heat pump for a house on a military base in Washington, D.C. given the following assumptions:

   - Initial purchase and installation cost = $1,500

   - Annual maintenance cost, constant $ = $50

   - Compressor replacement in year 8, constant $ = $400

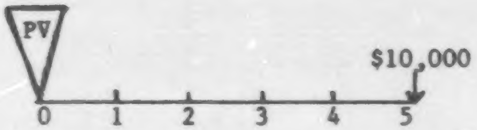
   - Salvage value (net of disposal costs) at end of life = $250

   - Useful life - 15 years

   - Annual electricity costs, valued at the beginning of the study period = $800

Flip Chart or Blackboard Solutions to Problems 1-5

1.

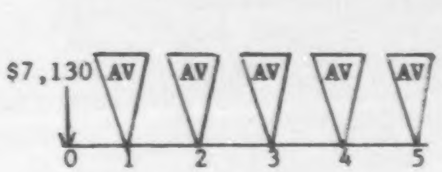

PV
$10,000
0
1
2
3
4
5

$\text{PV} = \text{F} \times \text{SPW}_{(5\text{yr},7\%)}$

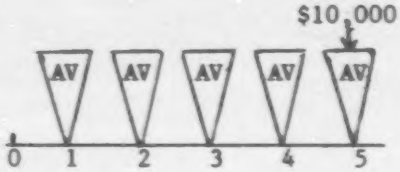
$= \$10{,}000 \times 0.7130^{*}$

$= \$7{,}130$

* Workbook p. 2-5. Discount factors from Appendix A of Handbook 135 are rounded to two decimal places, so they yield less precise answers.


$7,130
AV
AV
AV
AV
AV
0
1
2
3
4
5

or


$10,000
AV
AV
AV
AV
AV
0
1
2
3
4
5

$\text{AV} = \text{P} \times \text{UCR}_{(5\text{yr},7\%)}$

$= \$7{,}130 \times 0.2439$

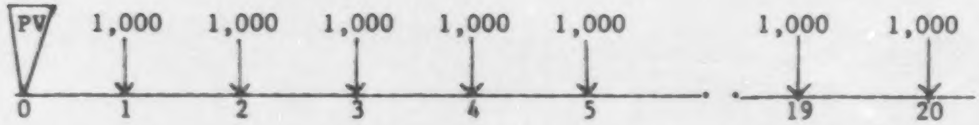
$= \$1{,}739$

$\text{AV} = \text{F} \times \text{USF}_{(5\text{yr},7\%)}$

$= \$10{,}000 \times 0.1739$

$= \$1{,}739$

2.

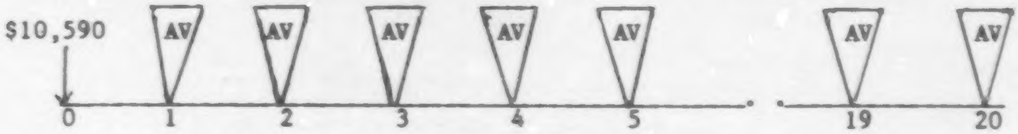

PV
1,000
1,000
1,000
1,000
1,000
1,000
1,000
0
1
2
3
4
5
19
20

PV = AV X UPW(20yr,7%)

= $1,000 X 10.59

= $10,590

[Note that the cost is given as an annual value in the problem statement, and demonstrate how the present value can be converted back to an annual value basis.]

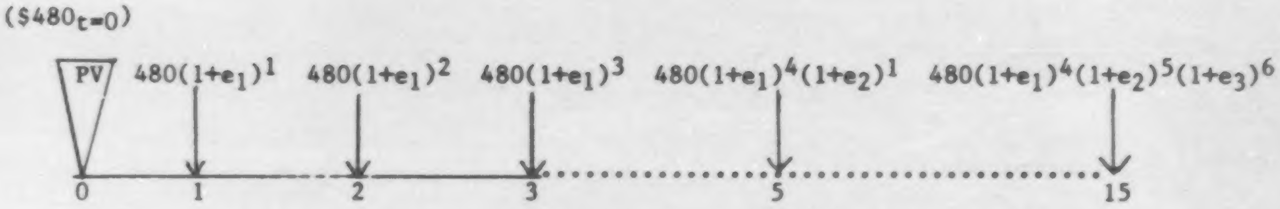

$10,590
AV
AV
AV
AV
AV
AV
AV
0
1
2
3
4
5
19
20

AV = PV X UCR(20yr,7%)

= $10,590 X .0944

= $1,000

3.


(480_{t=0}$)
PV
480(1+e$_1$)^1
480(1+e$_1$)^2
480(1+e$_1$)^3
480(1+e$_1$)^4(1+e$_2$)^1
480(1+e$_1$)^4(1+e$_2$)^5(1+e$_3$)^6
0
1
2
3
5
15

e_1 = 5.29% (Table C-3, p. 136)

e_2 = 0.66% (Table C-3, p. 136)

e_3 = 0.14% (Table C-3, p. 136)

[Note that if UPW*'s in Handbook 135 are still based on 1981 as base year, e_1 is used 4 years rather than 2.]

PV = \$/Unit X Units X UPW*(15yrs,7%,DoE3,Com,Elec) (Table B-3, p. 120)

= \$0.06/kWh X 8,000kWh X 11.07

= \$5,314

AV = PV X UCR

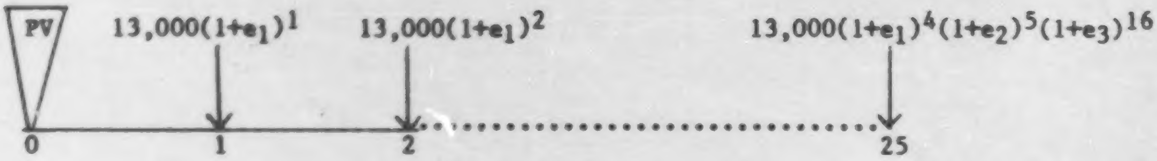
= \$5,314 X .1098

= \$583

[Note time-equivalencies and implied trade-offs between first cost and energy costs or annual non-energy costs and energy costs.]

4.

($13,000)


PV
$13{,}000(1+e_1)^1$
$13{,}000(1+e_1)^2$
$13{,}000(1+e_1)^4(1+e_2)^5(1+e_3)^{16}$
0
1
2
25

e_1 = 2.51%

e_2 = 2.66%

e_3 = 6.39%

PV = Price/Unit X Units X UPW*(25yrs,7%,Com,Dis)

= $1.30/gal X 10,000 gal X 17.77

= $231,010

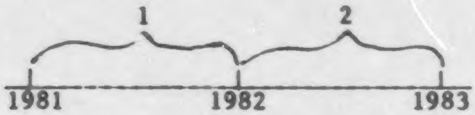
AV = PV X UCR

= $231,010 X .0858

= $19,821

5.

- o Explain that average U.S. price projections are found in Table C-11, p. 144 of Handbook 135.
- o Ask how the 1981 price might be updated using the data in Table C-11.
- o Derive the mid-1983 price from mid-1981 price as follows:



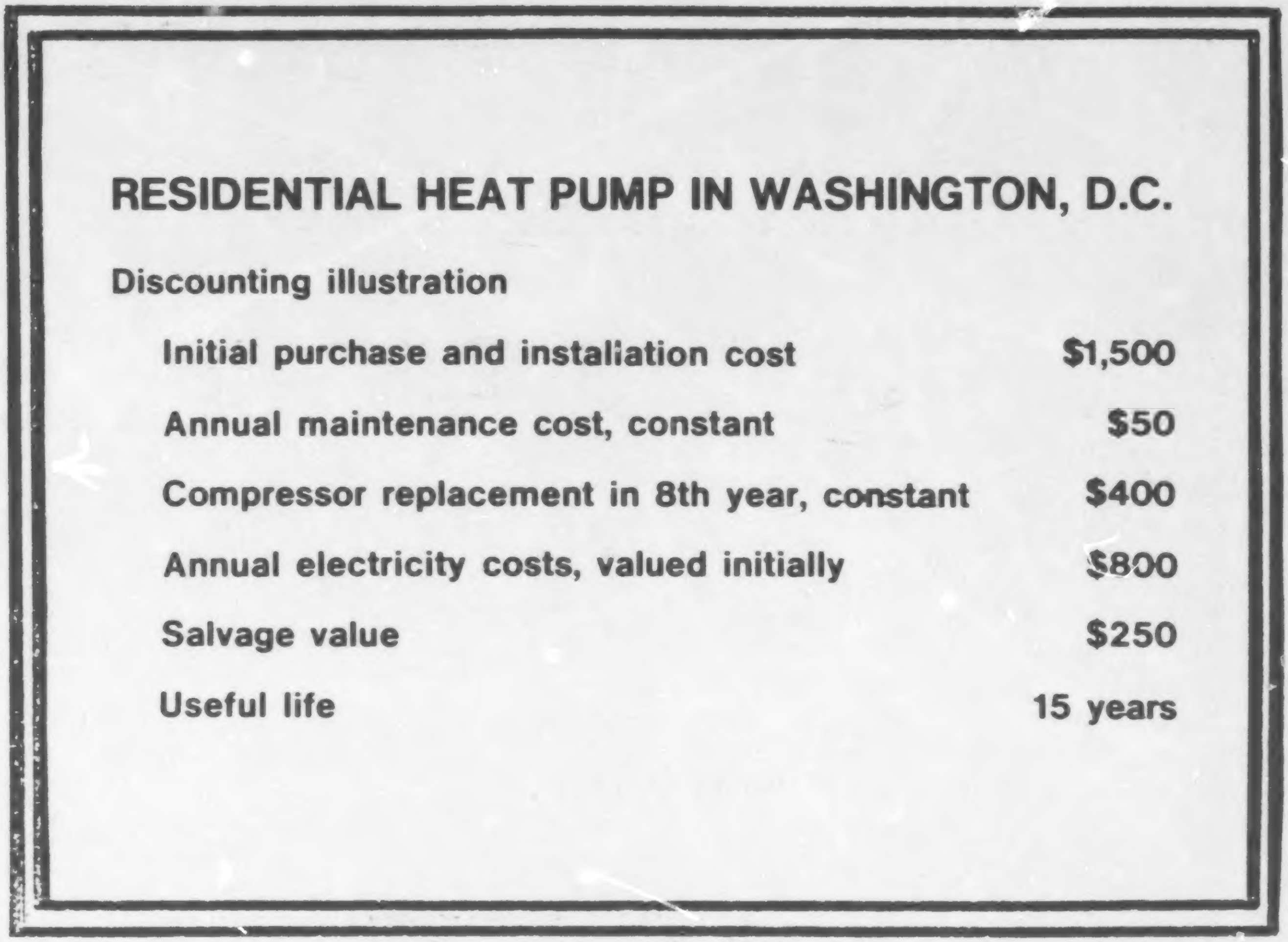
From Table C-11, $e_1 = 8.85\%$

$$P_{1983} = P_{1981} \times (1+e_1)^2$$

$$= \$0.004/ft^3\ (1+.0885)^2$$

$$= \$0.0047$$

Slide 10



RESIDENTIAL HEAT PUMP IN WASHINGTON, D.C.

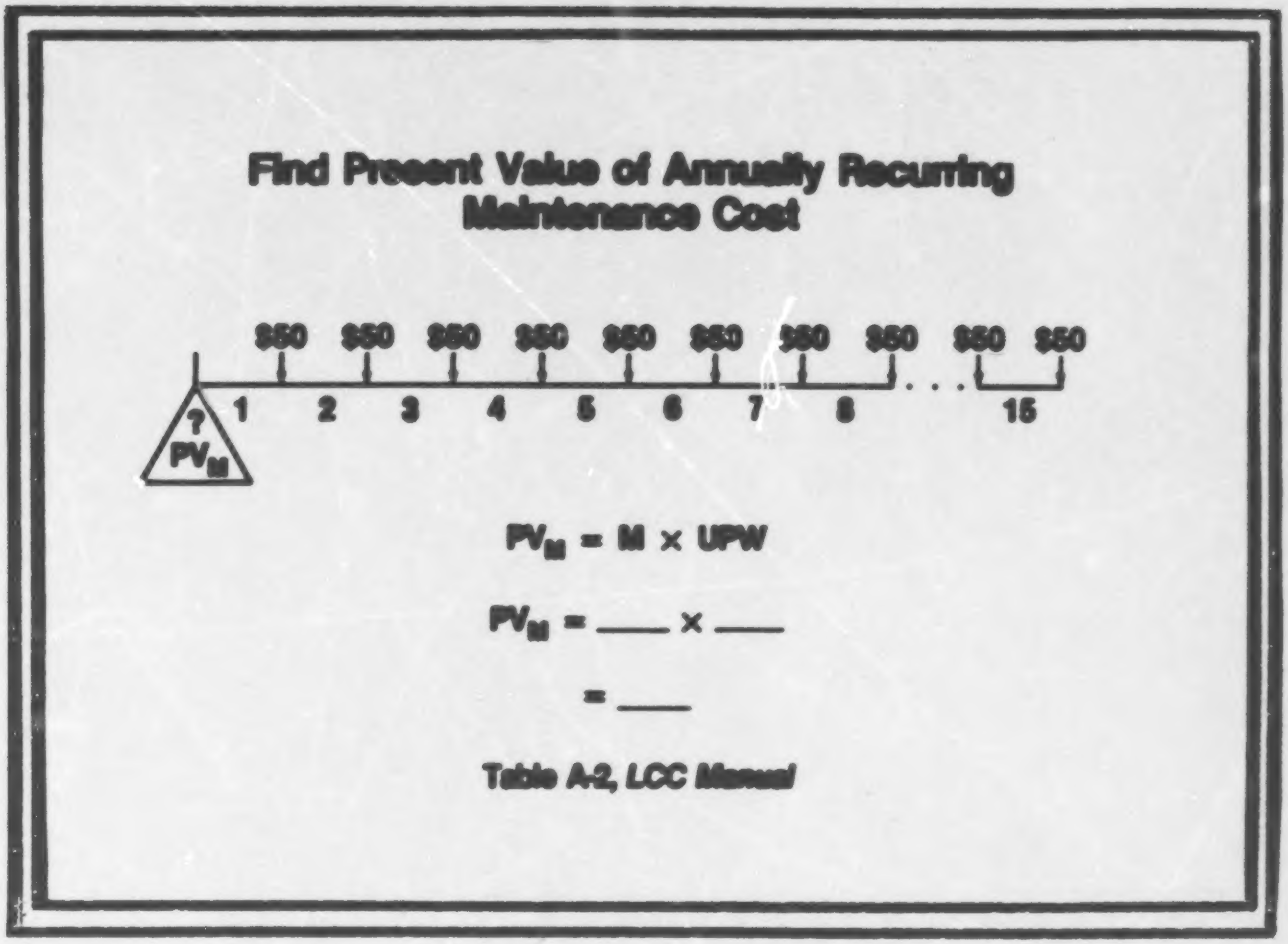
Discounting illustration

Initial purchase and installation cost	$1,500
Annual maintenance cost, constant	$50
Compressor replacement in 8th year, constant	$400
Annual electricity costs, valued initially	$800
Salvage value	$250
Useful life	15 years

Residential Heat Pump in Washington, D.C.

- o Explain that Problem #6 of Workbook Problem Set A has a number of different cash flows.
- o Ask them to compute a total present value cost for the heat pump.
- o Note that salvage value is a positive cash flow.

Slide 11



Find Present Value of Annually Recurring Maintenance Cost

$50
$50
$50
$50
$50
$50
$50
$50
$50
$50
1
2
3
4
5
6
7
8
. . .
15
?
PV_M

$$PV_M = M \times UPW$$

$$PV_M = \_\_\_\_ \times \_\_\_\_$$

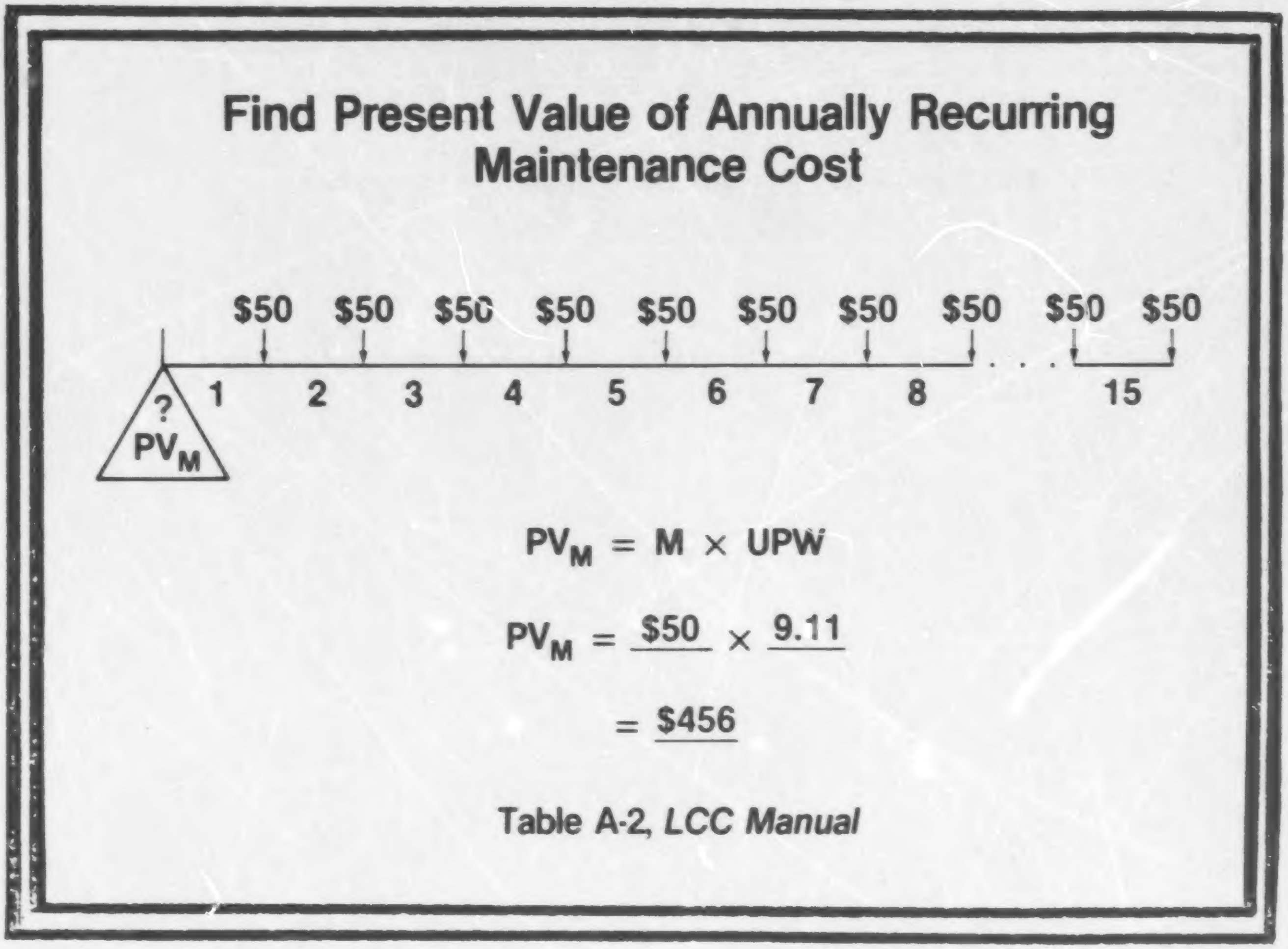
$$= \_\_\_\_$$

Table A-2, LCC Manual

Find Present Value of Annually Recurring Maintenance Cost

- o Show the approach.
- o Ask for answer.

Slide 12



Find Present Value of Annually Recurring Maintenance Cost

$50
$50
$50
$50
$50
$50
$50
$50
$50
$50
1
2
3
4
5
6
7
8
15
?
PV_M

$$PV_M = M \times UPW$$

$$PV_M = \underline{\$50} \times \underline{9.11}$$

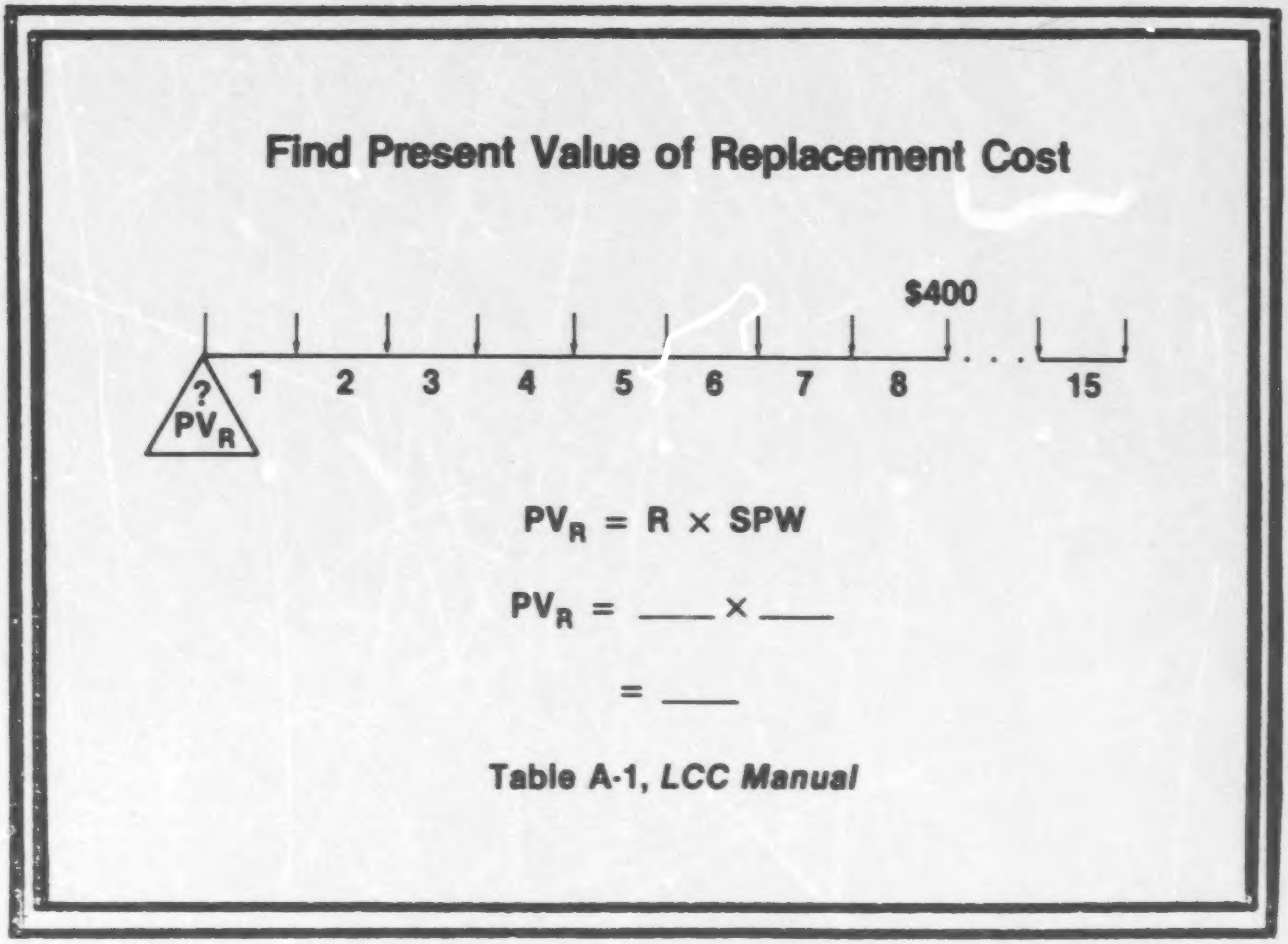
$$= \underline{\$456}$$

Table A-2, *LCC Manual*

Find Present Value of Annually Recurring Maintenance Cost

- o Give solution.

Slide 13



Find Present Value of Replacement Cost

$400
?
PV_R
1
2
3
4
5
6
7
8
15

$$PV_R = R \times SPW$$

$$PV_R = \_\_\_\_ \times \_\_\_\_$$

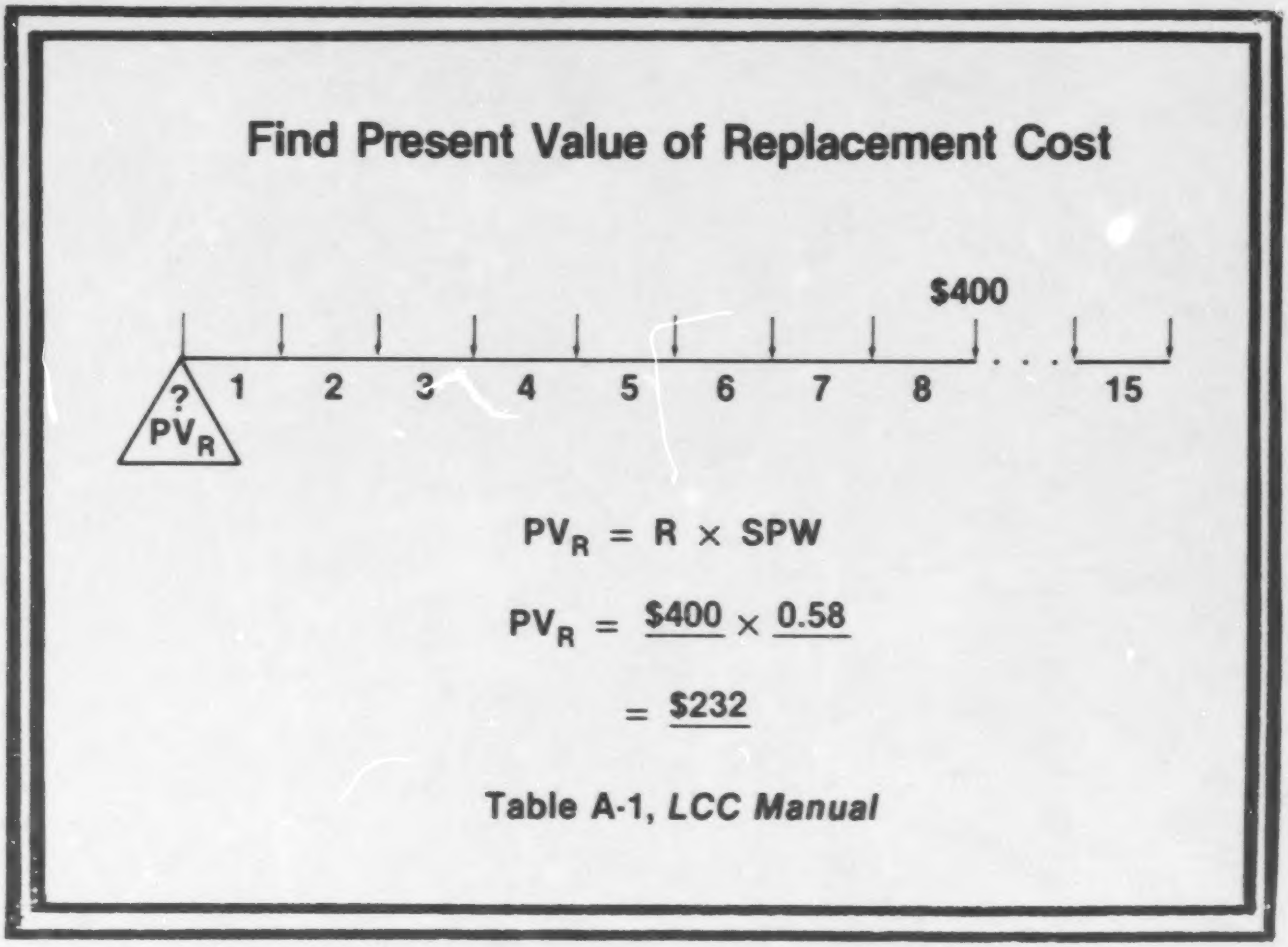
$$= \_\_\_\_$$

Table A-1, *LCC Manual*

Find Present Value of Replacement Cost

- Show approach.
- Ask for answer.

Slide 14



Find Present Value of Replacement Cost

$$PV_R = R \times SPW$$

$$PV_R = \underline{\$400} \times \underline{0.58}$$

$$= \underline{\$232}$$

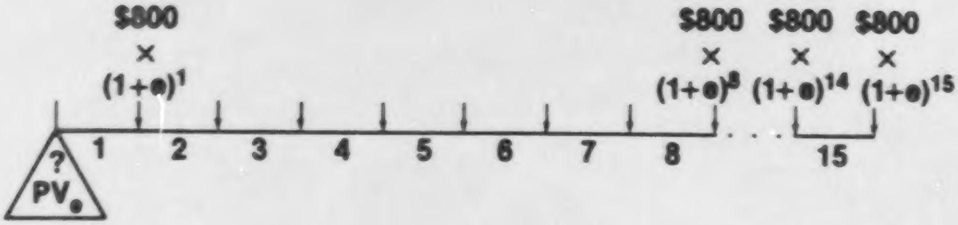
Table A-1, *LCC Manual*

Find Present Value of Replacement Cost

- Give solution.

Slide 15

Find Present Value of Energy Costs



$800
×
$(1+e)^1$
$800
×
$(1+e)^8$
$800
×
$(1+e)^{14}$
$800
×
$(1+e)^{15}$
?
PV_e
1
2
3
4
5
6
7
8
. . .
15

$$PV_e = E_e \times UPW_e^*$$

$$PV_e = \_\_\_\_ \times \_\_\_\_$$

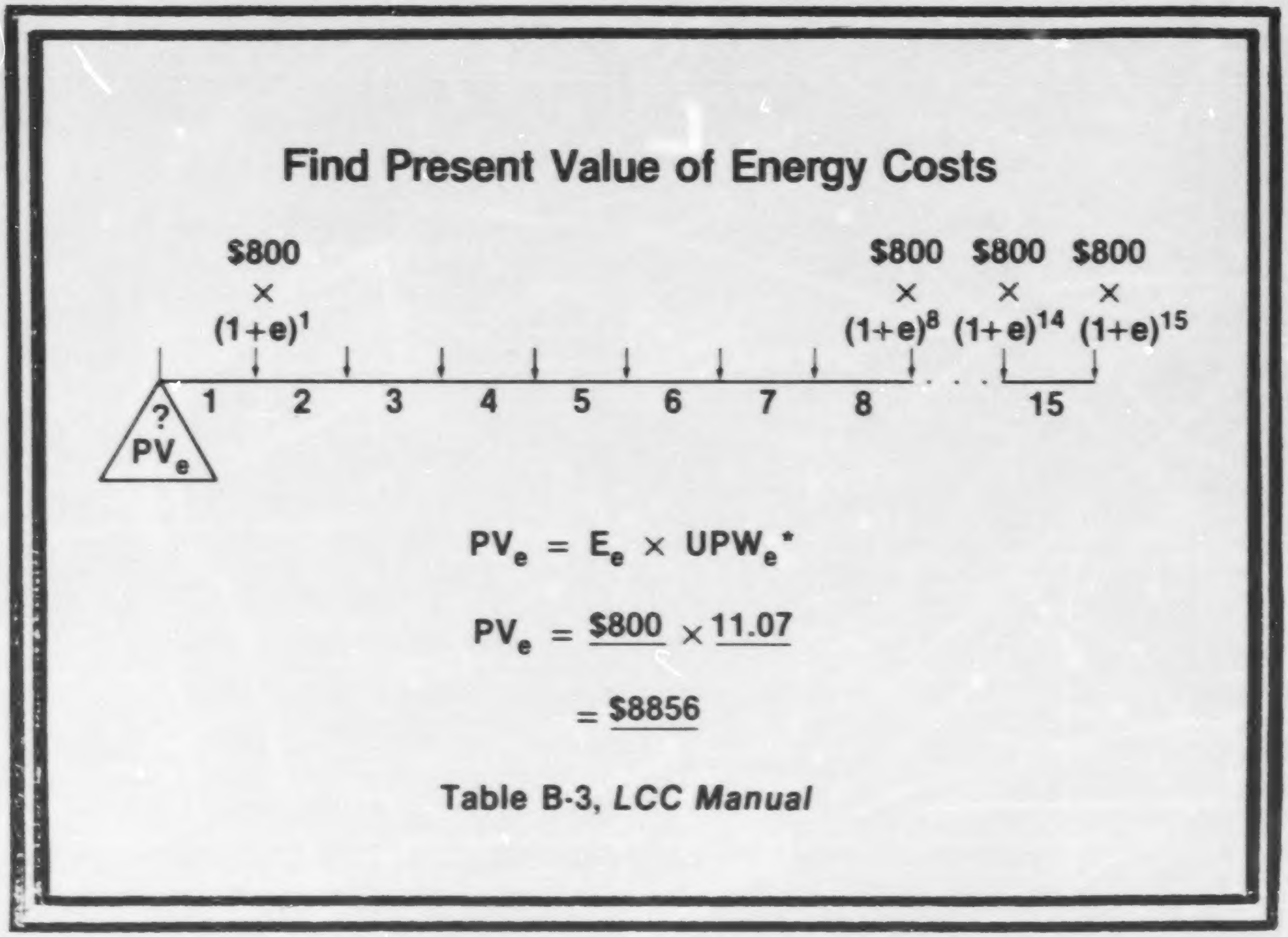
$$= \_\_\_\_$$

Table B-3, *LCC Manual*

Find Present Value of Energy Costs

- Show approach.
- Ask for answer.

Slide 16



Find Present Value of Energy Costs

$800 × $(1+e)^1$
$800 × $(1+e)^8$
$800 × $(1+e)^{14}$
$800 × $(1+e)^{15}$
1
2
3
4
5
6
7
8
15
? PV_e

$$PV_e = E_e \times UPW_e^*$$

$$PV_e = \underline{\$800} \times \underline{11.07}$$

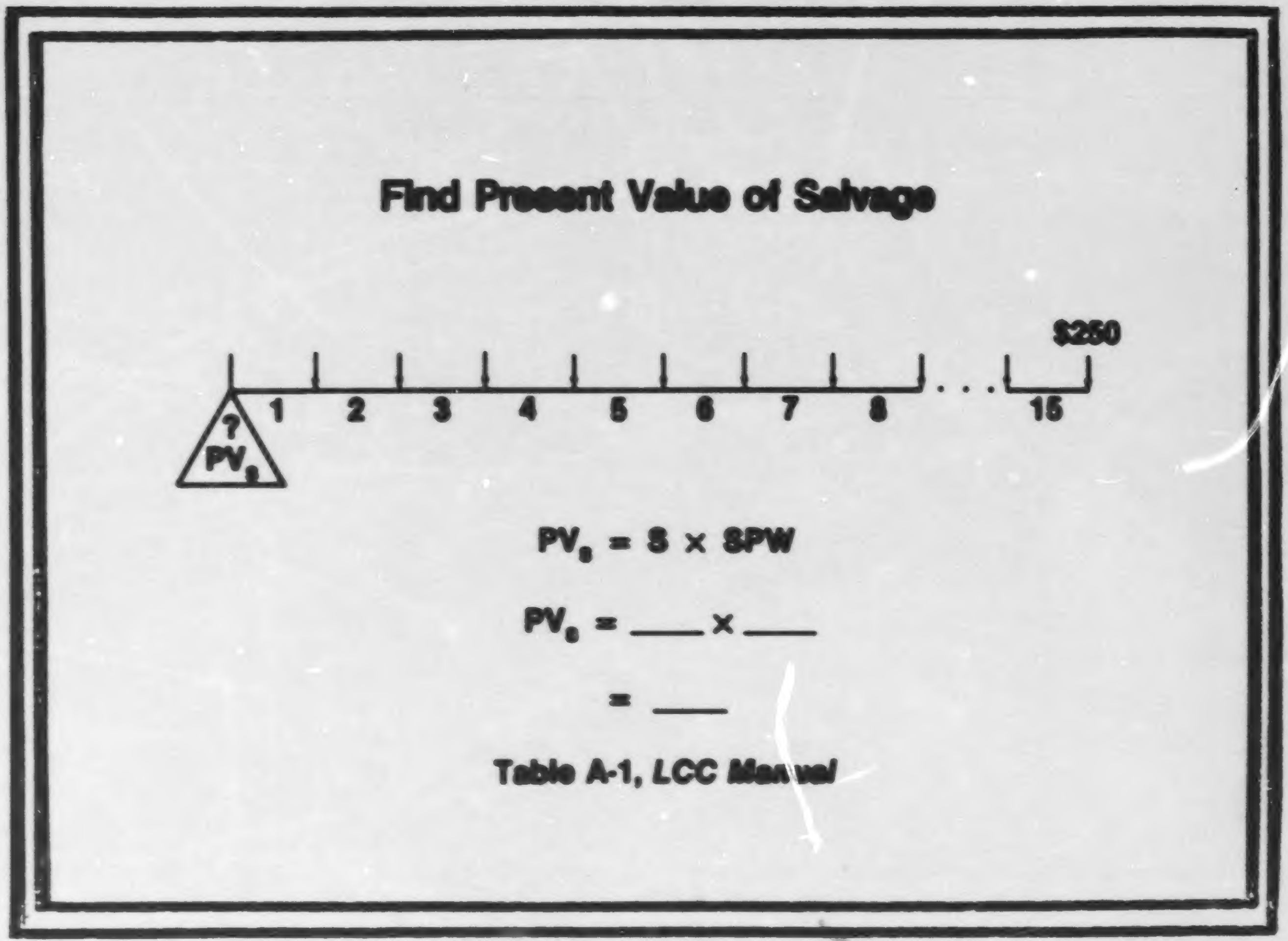
$$= \underline{\$8856}$$

Table B-3, *LCC Manual*

Find Present Value of Energy Costs

- Give solution.

Slide 17


$250
1
2
3
4
5
6
7
8
15
?
PV_s

Find Present Value of Salvage

$$PV_s = S \times SPW$$

$$PV_s = \_\_\_ \times \_\_\_$$

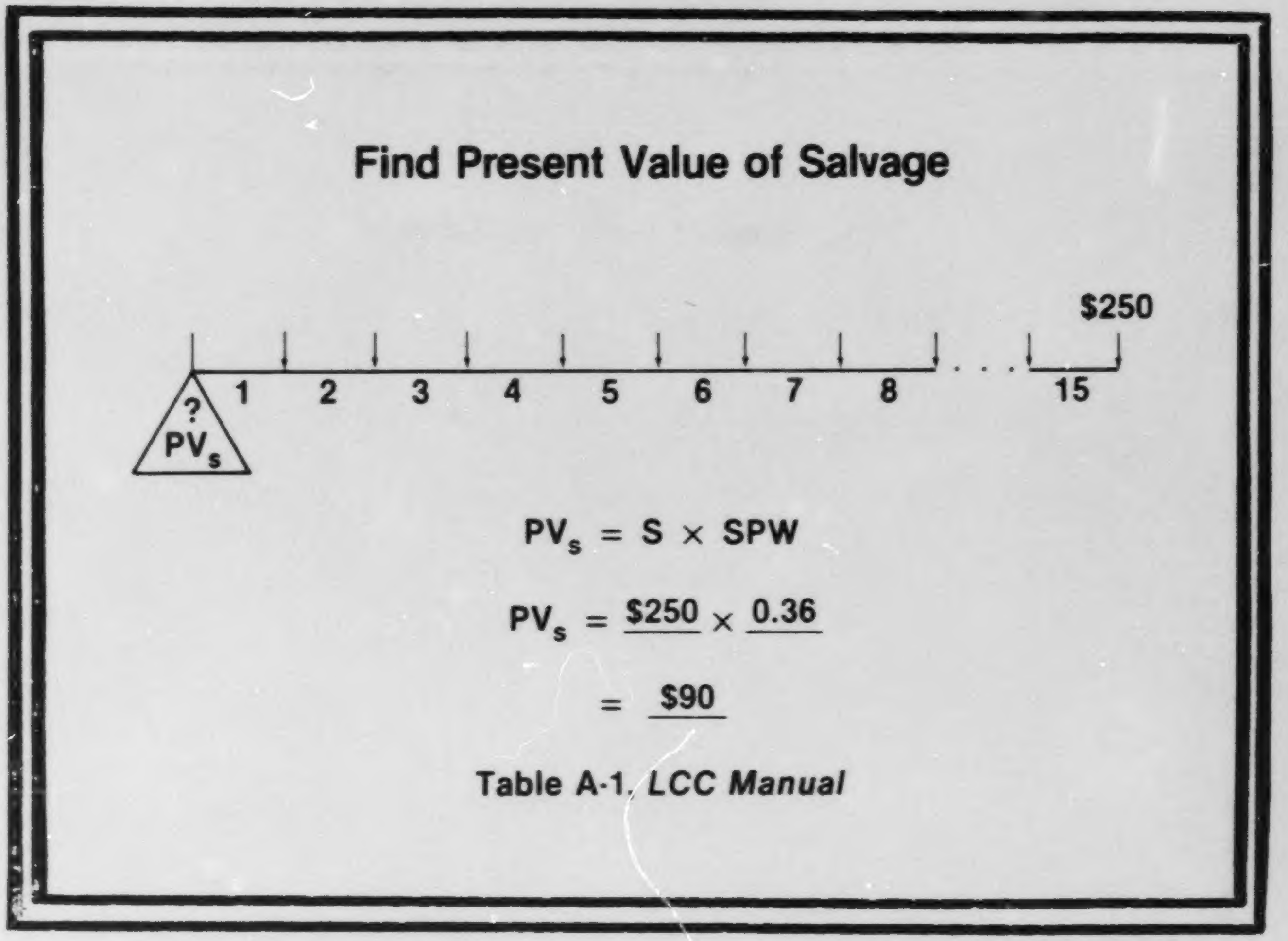
$$= \_\_\_$$

Table A-1, *LCC Manual*

Find Present Value of Salvage

- o Show approach.
- o Ask for answer.

Slide 18



Find Present Value of Salvage

$$PV_s = S \times SPW$$

$$PV_s = \underline{\$250} \times \underline{0.36}$$

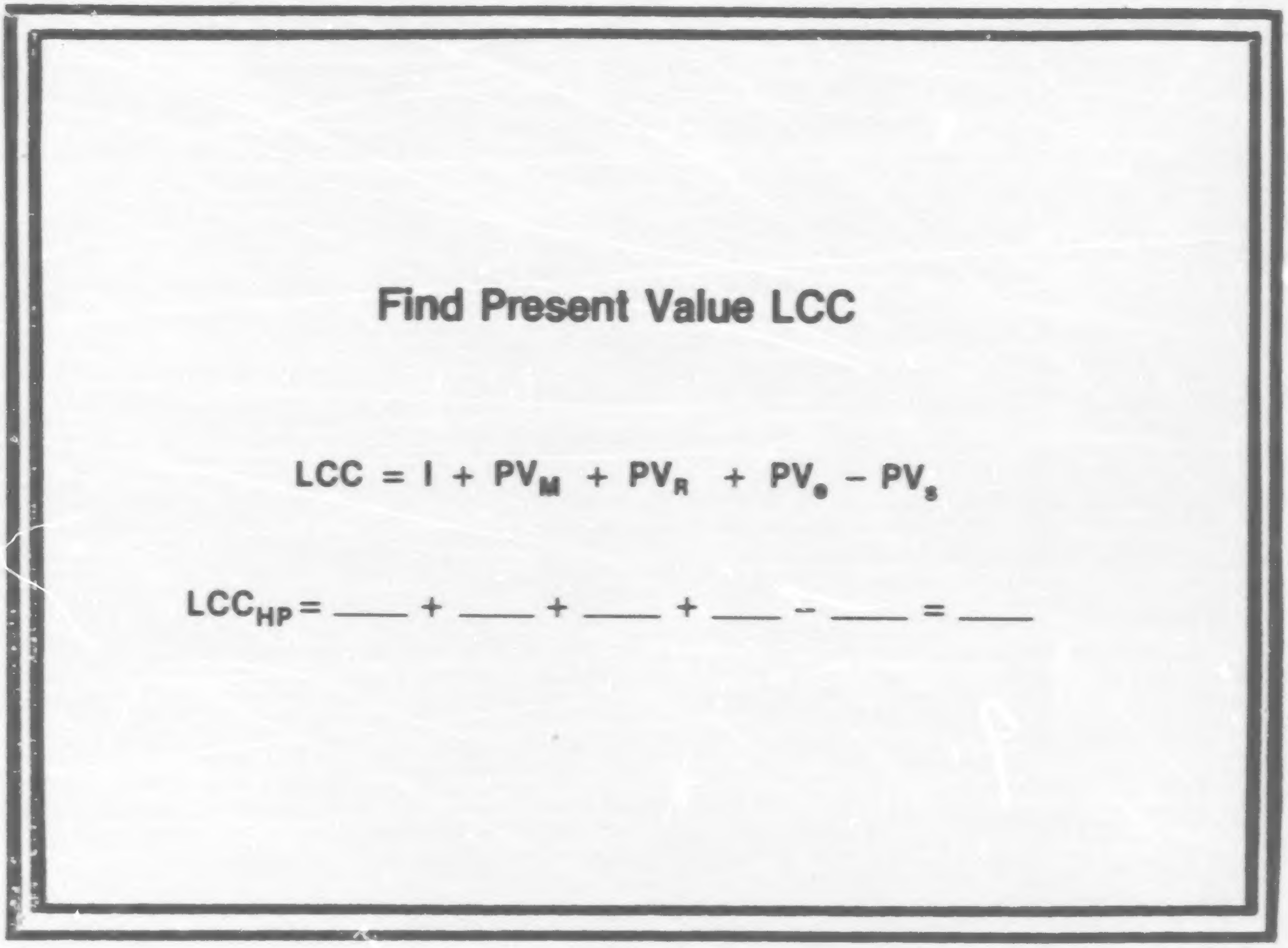
$$= \underline{\$90}$$

Table A-1, *LCC Manual*

Find Present Value of Salvage

o Give solution.

Slide 19



Find Present Value LCC

$$LCC = I + PV_M + PV_R + PV_e - PV_s$$

LCC_{HP} = ____ + ____ + ____ + ____ - ____ = ____

Find Present Value LCC

- o Show approach.
- o Ask for answer.

Slide 20

Find Present Value LCC

$$LCC = I + PV_M + PV_R + PV_e - PV_s$$

$$LCC_{HP} = \underline{1500} + \underline{\ 456\ } + \underline{\ 232\ } + \underline{8856} - \underline{\ \ 90\ \ } = \underline{\$10{,}954}$$

Find Present Value LCC

- Give solution.

Section 6

Presentation: LCC, NS, BCR, SIR, IRR, and PB Analysis

The purposes of this session are to (1) identify the conventional economic evaluation methods that are generally applied to building-related decisions, (2) present and explain for each method the formulas for calculating economic measures of a project's worth, and (3) recommend appropriate economic methods for the various economic decisions made by the building community.

Slide 1

MEASURES OF ECONOMIC PERFORMANCE

- **Total Life-Cycle Costs (TLCC)**
- **Net Savings (NS)**
- **Savings-to-Investment Ratio (SIR)**
- **Internal Rate of Return (IRR)**
- **Payback Period (PB)**
    - **Simple (SPB)**
    - **Discounted (DPB)**

Measures of Economic Performance

- o Present introduction.
- o Identify each of the 5 measures.
- o Give a brief example of their use.

Slide 2

TOTAL LIFE-CYCLE COSTS (TLCC)

$$\text{TLCC} = I - S + M + R + E$$

Total Life-Cycle Costs (TLCC)

- Explain the equation.
- Note that all items are assumed to be discounted.
- Explain how alternative building designs or different R values of insulation could be compared using the TLCC method.
- Refer the class to pp. 16 and 17 in Handbook 135 for elaboration on the TLCC method.

Slide 3

NET SAVINGS (NS or TLCS)

$$NS = TLCC_{WO} - TLCC_{W}$$

Net Savings (NS or TLCS)

- o Explain the equation.
- o Explain how the installation of a heat pump can be evaluated by calculating NS.
- o Refer the class to pp. 17, 18, and 19 of Handbook 135 for elaboration on the NS method.

Slide 4

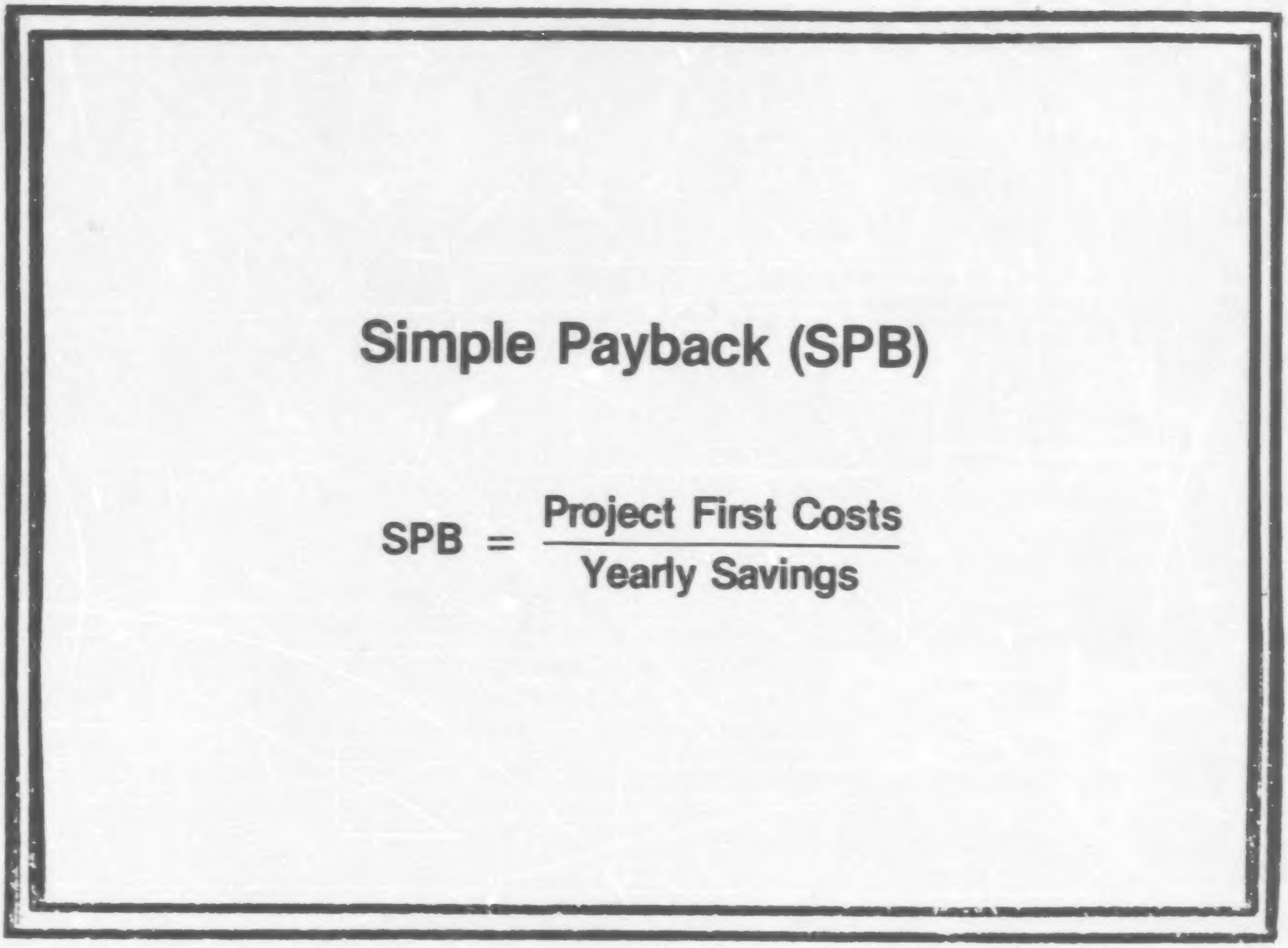
SAVINGS-TO-INVESTMENT RATIO (SIR)

$$SIR = (\Delta E - \Delta M) / (\Delta I - \Delta S + \Delta R)$$

Savings-to-Investment Ratio (SIR)

- o Explain equation.
- o Discuss why each term is in denominator or numerator. Assuming that the investment objective is to maximize the return on the capital budget, cost items in the current or operating budget are placed in the numerator, and those in the capital budget in the denominator.
- o Explain how alternative conservation investments in buildings could be evaluated with the SIR method.
- o Note that the answer is a ratio, and that conceptually it is equivalent to the benefit-to-cost ratio where benefits would be equivalent to savings.
- o Refer the class to p. 19 of Handbook 135 for an elaboration of the SIR method.

Slide 5



Simple Payback (SPB)

$$SPB = \frac{\text{Project First Costs}}{\text{Yearly Savings}}$$

Simple Payback

- Explain the formula.
- Note that the answer is in years.
- Explain how SPB could be used to evaluate a retrofit control device.
- Describe main shortcomings: (1) terms are not discounted, and (2) net savings are ignored beyond the payback year.
- Refer the class to pp. 20-21 of Handbook 135 for elaboration of the SPB method.

Slide 6

DISCOUNTED PAYBACK (DPB)

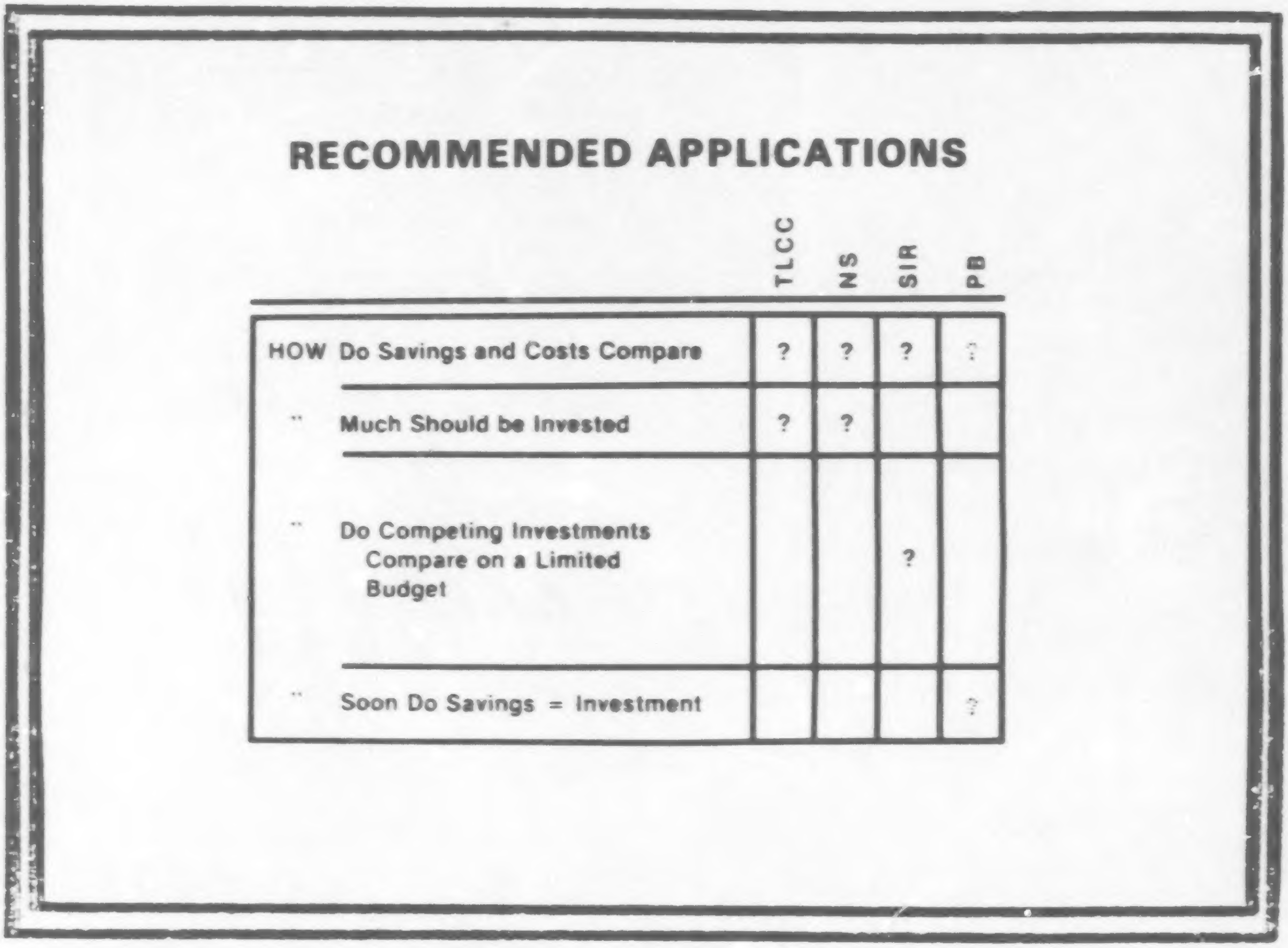
Find y such that

$$\sum_{j=1}^{y} (\Delta E_j - \Delta M_j - \Delta R_j + \Delta S_j) = \Delta I$$

Discounted Payback

- Explain the equation.
- Note that the answer is still in years.
- Describe advantages: (1) discounting is included, and (2) uneven yearly cash flows are allowed for.
- Describe main shortcoming that net savings are ignored beyond the payback year.
- Refer the class to pp. 20-21 of Handbook 135 for elaboration of the DPB method.

Slide 7



RECOMMENDED APPLICATIONS

		TLCC	NS	SIR	PB
HOW	Do Savings and Costs Compare	?	?	?	?
"	Much Should be Invested	?	?		
"	Do Competing Investments Compare on a Limited Budget			?	
"	Soon Do Savings = Investment				?

Recommended Applications

- Describe how each question can be addressed by the four methods.
- Reiterate that the TLCC and NS methods yield dollar values, whereas the SIR yields a ratio and the PB the number of years to payoff.

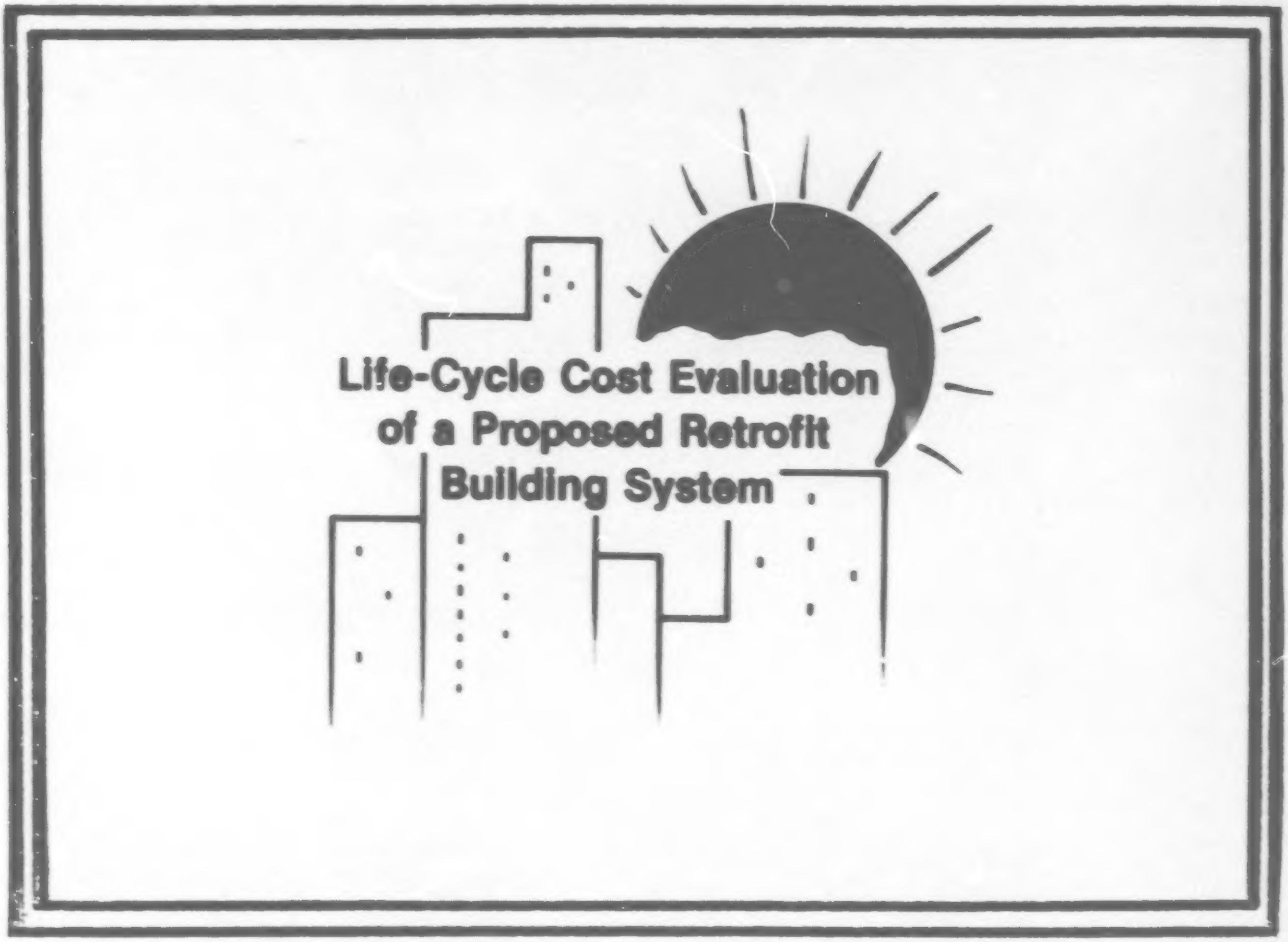
Section 7

Slide Presentation: Pipe Insulation Retrofit Problem

The purpose of this session is to demonstrate the use of the economic evaluation methods described in the preceding sessions in a practical problem of energy conservation. The session is based on the Pipe Insulation Retrofit Problem in Section 5 of the Workbook, entitled Project Selection.

Ask the class to turn to that section of the Workbook and follow along so that the material will be familar as a reference guide to project selection.

Slide 1



Life-Cycle Cost Evaluation of a Proposed Retrofit Building System

Life-Cycle Cost Evaluation of a Proposed Retrofit Building System

- Explain purpose of the session.
- Direct the class to the Problem Illustration in Section 5 of the Workbook, Project Selection.

Slide 2

LCC PROBLEM

Insulation of Bare Hot Water Pipes
in a
Federal Laboratory Facility
in
Massachusetts

- Cost Effective?
- How Much?
- Project Priority?

LCC Problem

- Explain the problem and what is to be decided.

Slide 3

Problem Assumptions

- Quantity Uninsulated Pipe: 100 Ft/Bldg × 10 Bldgs = 1000 Ft
- Water Temp: 180°
- Pipe Size: 1 ½" Diameter
- Operation: 4 Hrs/Day × 260 Days/Yr = 1,040 Hrs/Y
- Energy System: Distillate Fired Boiler; .55 Efficiency
- Remaining Building Life: Indefinite
- Investment Life: Indefinite
- Available Alternatives: 1" Insulation
  or
  2" Insulation

Problem Assumptions

o Review the problem assumptions.

o Explain that in a real application, one would look for other conservation alternatives, such as reducing the water temperature or increasing the efficiency of the plant. However, in this example, it is assumed that there are no other alternatives.

Slide 4

Annual Energy Savings (10^6 Btu)

$$AES = (\Delta HLR/hr/ft \times hrs \times ft)/eff. \times 10^6$$

1" Insulation

$$AES_{1"} = [(150\text{-}20\ Btu/hr/ft) \times 1{,}040\ hrs \times 1{,}000\ ft]/0.55 \times 10^6$$
$$= 245.8$$

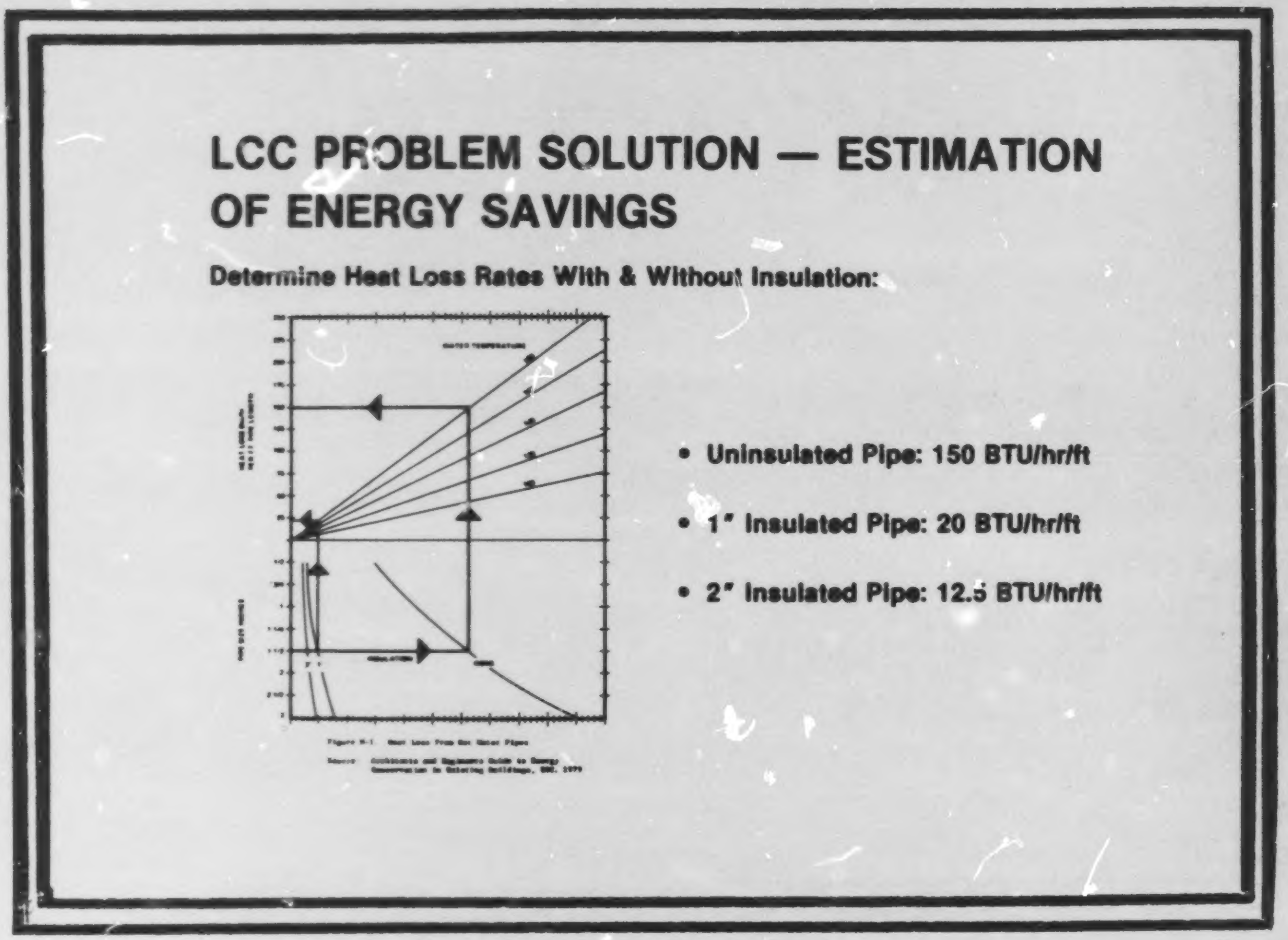
2" Insulation

$$AES_{2"} = [(150\text{-}12.5\ Btu/hr/ft) \times 1{,}040\ hrs \times 1{,}000\ ft]/0.55 \times 10^6$$
$$= 260.0$$

Annual Energy Savings

- o Direct the class to Step 1 of the Workbook problem solution: Calculate the quantity of annual energy savings for the alternative sizes of insulation.
- o Explain the equation.
- o Direct them to the Nomograph in the Workbook which shows the heat loss rates for various pipe sizes, insulation thickness, and water temperatures.
- o Explain that this nomograph is an example of an existing estimating aid that can greatly reduce the evaluation time.

Slide 5



LCC PROBLEM SOLUTION — ESTIMATION OF ENERGY SAVINGS

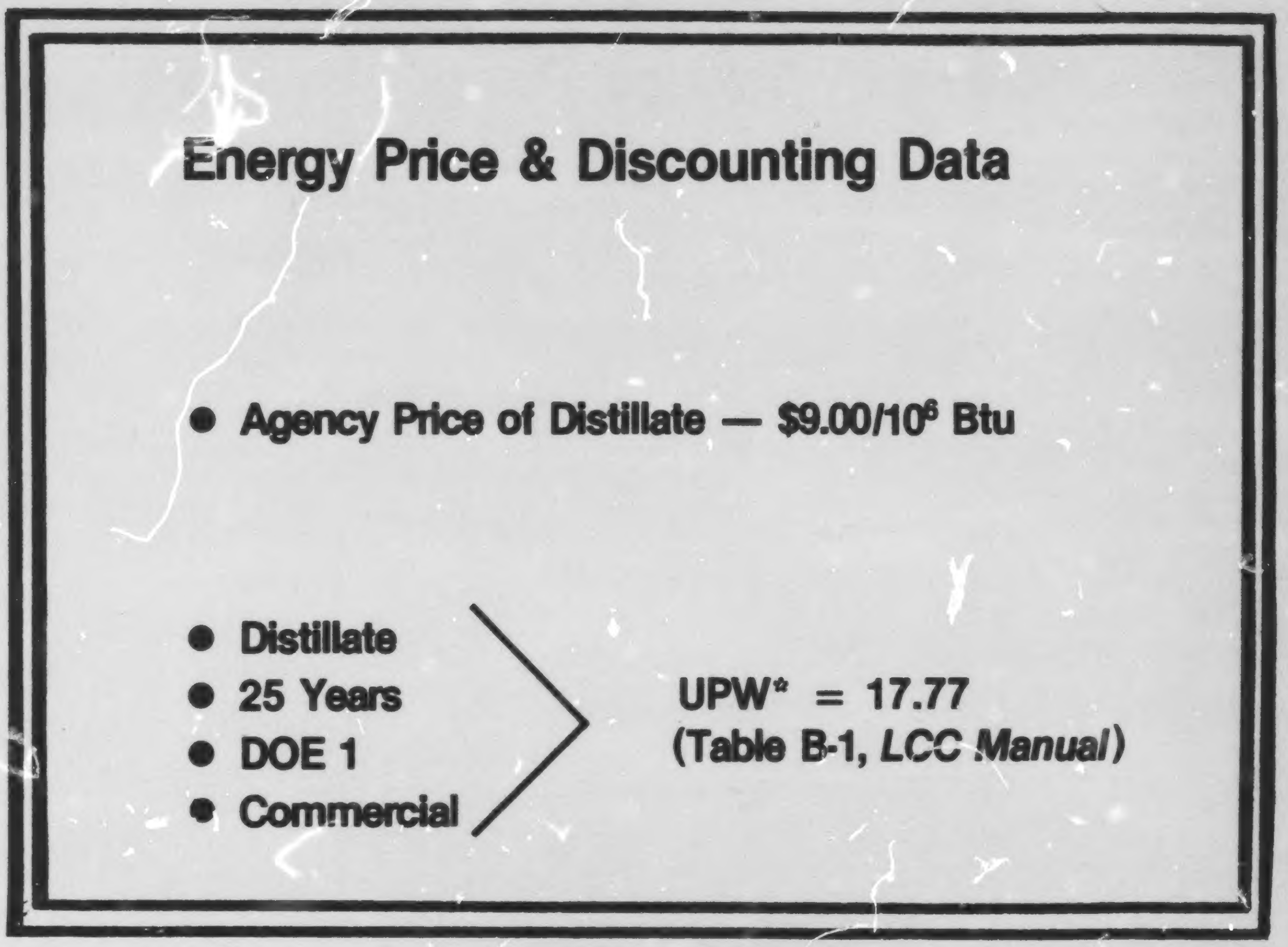
Determine Heat Loss Rates With & Without Insulation:

- **Uninsulated Pipe: 150 BTU/hr/ft**
- **1" Insulated Pipe: 20 BTU/hr/ft**
- **2" Insulated Pipe: 12.5 BTU/hr/ft**

LCC Problem Solution — Estimation of Energy Savings

o Explain how the nomograph is used to derive the heat loss rates given in the preceding slide.

Slide 6



Energy Price & Discounting Data

- Agency Price of Distillate — \$9.00/10^6 Btu

- Distillate
- 25 Years
- DOE 1
- Commercial

UPW* = 17.77
(Table B-1, *LCC Manual*)

Energy Price and Discounting Data

- Refer the class to Step 2 of the Workbook solution.

- Point out the need for an initial energy cost per unit and a UPW* factor to estimate the present value of savings.

Slide 7

LCC Energy Savings (Present Value $)

$$ES_{LCC} = AES \times \$/10^6\ \text{Btu} \times UPW^*$$

1" Insulation

$$ES_{LCC_{1"}} = 245.8 \times 10^6\ \text{Btu} \times \$9.00/10^6\ \text{Btu} \times 17.77$$
$$= \$39,311$$

2" Insulation

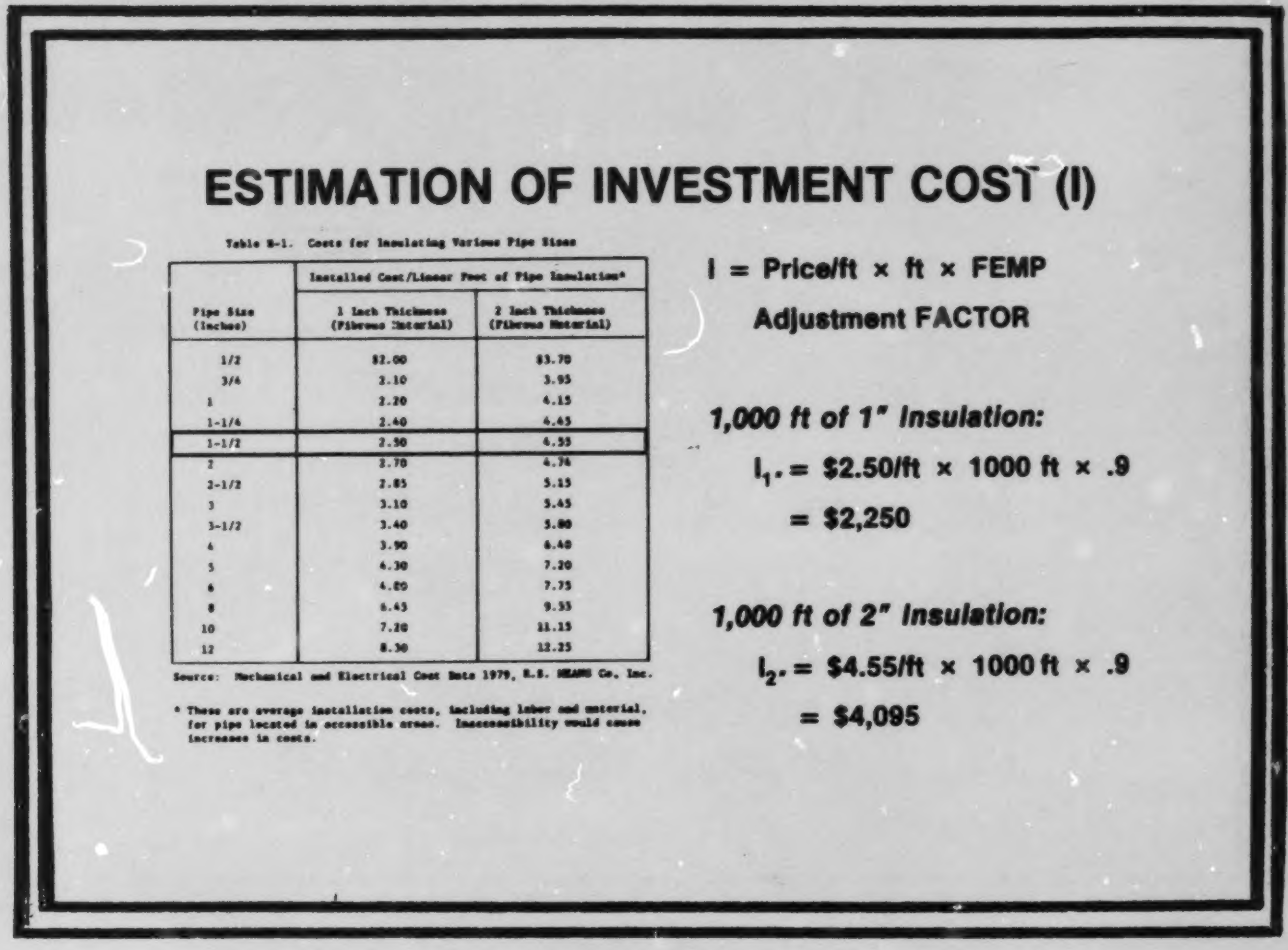
$$ES_{LCC_{2"}} = 260.0 \times 10^6\ \text{Btu} \times \$9.00/10^6\ \text{Btu} \times 17.77$$
$$= \$41,582$$

LCC Energy Savings

- Review calculation procedure.
- Ask class if the questions can be answered yet.

BEST COPY AVAILABLE

Slide 8



ESTIMATION OF INVESTMENT COST (I)

Table 5-1. Costs for Insulating Various Pipe Sizes

Pipe Size (Inches)	Installed Cost/Linear Foot of Pipe Insulation*	
	1 Inch Thickness (Fibrous Material)	2 Inch Thickness (Fibrous Material)
1/2	$2.00	$3.70
3/4	2.10	3.95
1	2.20	4.15
1-1/4	2.40	4.45
1-1/2	2.50	4.55
2	2.70	4.75
2-1/2	2.85	5.15
3	3.10	5.45
3-1/2	3.40	5.80
4	3.90	6.40
5	4.30	7.20
6	4.80	7.75
8	6.45	9.55
10	7.20	11.15
12	8.30	12.25

Source: Mechanical and Electrical Cost Data 1979, R.S. MEANS Co., Inc.

* These are average installation costs, including labor and material, for pipe located in accessible areas. Inaccessibility would cause increases in costs.

I = Price/ft × ft × FEMP Adjustment FACTOR

1,000 ft of 1" Insulation:

$$I_1 = \$2.50/\text{ft} \times 1000\ \text{ft} \times .9$$

$$= \$2{,}250$$

1,000 ft of 2" Insulation:

$$I_2 = \$4.55/\text{ft} \times 1000\ \text{ft} \times .9$$

$$= \$4{,}095$$

Estimation of Investment Cost

- Refer the class to Step 3 of the Workbook solution and to Table 5-1.

- Point out that this is cost data from a MEANS Cost Estimating Manual.

- Explain that the FEMP Adjustment Factor (i.e., 1.00-0.10 = 0.9) is a rough proxy for social benefits from energy conservation which are not fully reflected by market prices of energy. It was modeled after the 10% business tax credit for energy conservation investments that was in effect at the time this rule was developed. It is regarded as temporary and will likely be dropped at some point.

- Discuss its shortcomings.

Slide 9

LCC Net Savings

$$NS = ES_{LCC} - I$$

1" Insulation

$$NS_{1"} = \$39,311 - \$2,250 = \$37,061$$

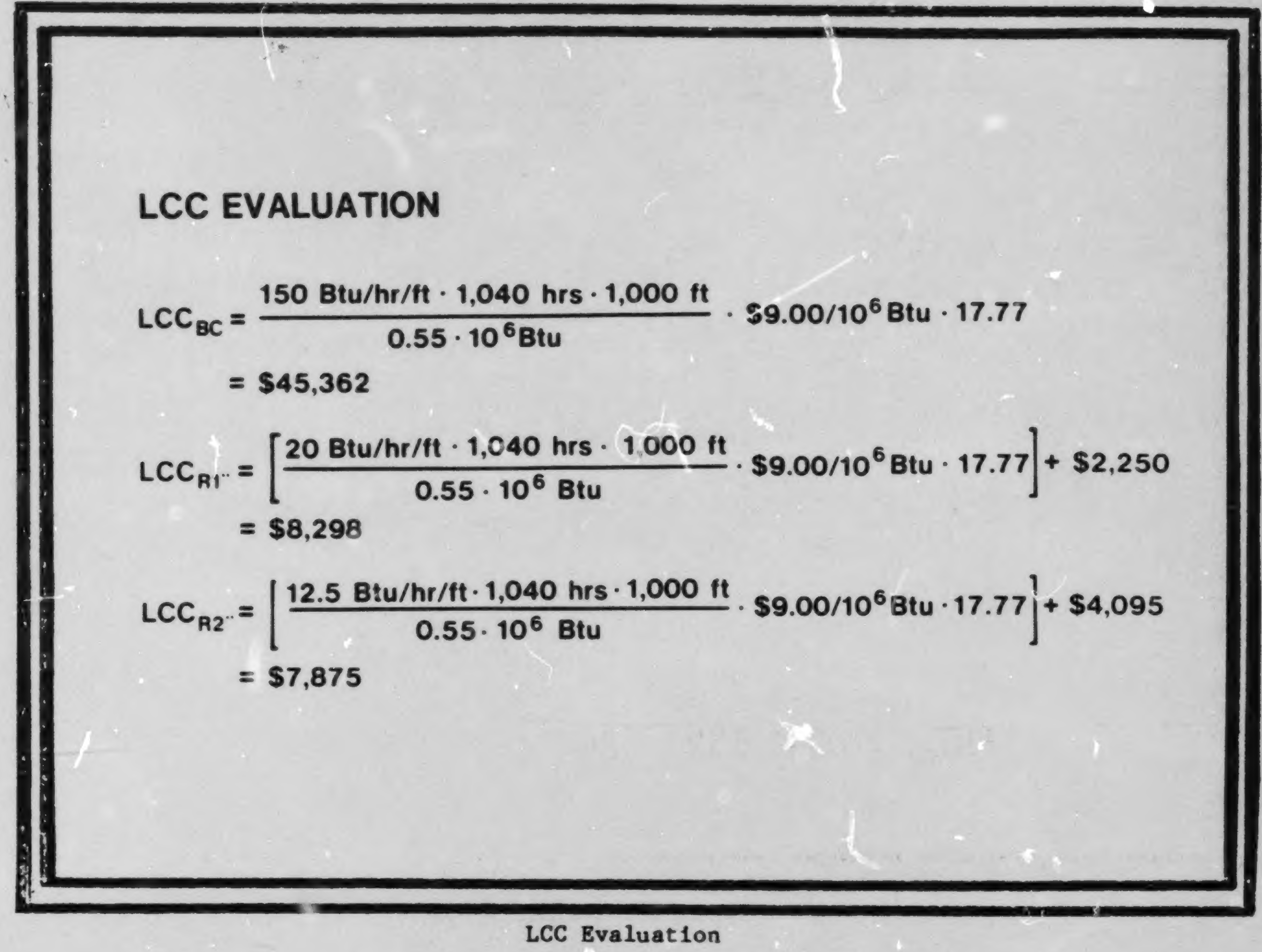
2" Insulation

$$NS_{2"} = \$41,582 - \$4,095 = \$37,487$$

LCC Net Savings

- o Refer the class to Step 4 of the Workbook solution.
- o Ask if it is estimated to be cost effective to insulate the pipes.
- o Ask why.
- o Ask how much — 1" or 2" — appears to be best at this point, noting in response that 2" appears preferred because it results in higher net savings.

Slide 10



LCC EVALUATION

$$LCC_{BC} = \frac{150\ \text{Btu/hr/ft} \cdot 1{,}040\ \text{hrs} \cdot 1{,}000\ \text{ft}}{0.55 \cdot 10^{6}\text{Btu}} \cdot \$9.00/10^{6}\,\text{Btu} \cdot 17.77$$

$$= \$45{,}362$$

$$LCC_{R1} = \left[\frac{20\ \text{Btu/hr/ft} \cdot 1{,}040\ \text{hrs} \cdot 1{,}000\ \text{ft}}{0.55 \cdot 10^{6}\ \text{Btu}} \cdot \$9.00/10^{6}\,\text{Btu} \cdot 17.77\right] + \$2{,}250$$

$$= \$8{,}298$$

$$LCC_{R2} = \left[\frac{12.5\ \text{Btu/hr/ft} \cdot 1{,}040\ \text{hrs} \cdot 1{,}000\ \text{ft}}{0.55 \cdot 10^{6}\ \text{Btu}} \cdot \$9.00/10^{6}\,\text{Btu} \cdot 17.77\right] + \$4{,}095$$

$$= \$7{,}875$$

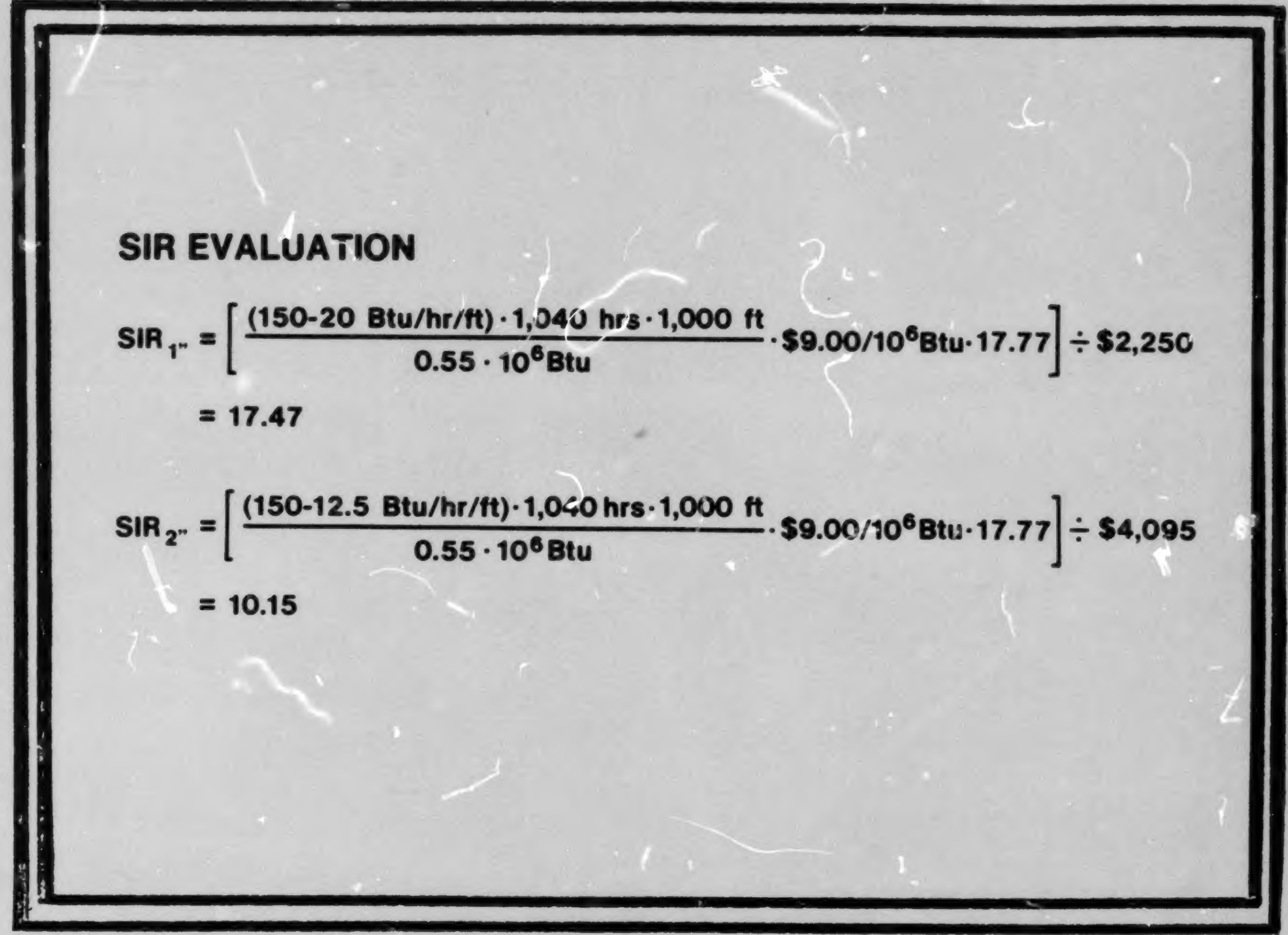
LCC Evaluation

- Refer the class to Step 6 in the Workbook solution, noting that the net savings method was adequate for addressing the question of cost effectiveness and that it would not be necessary to verify the answer by the other techniques. Rather, the purpose is to illustrate their use.

- Go through the LCC evaluation.

- Ask what the results indicate.

Slide 11



SIR EVALUATION

$$SIR_{1''} = \left[\frac{(150\text{-}20\ \text{Btu/hr/ft}) \cdot 1{,}040\ \text{hrs} \cdot 1{,}000\ \text{ft}}{0.55 \cdot 10^6\text{Btu}} \cdot \$9.00/10^6\text{Btu} \cdot 17.77\right] \div \$2{,}250$$

$$= 17.47$$

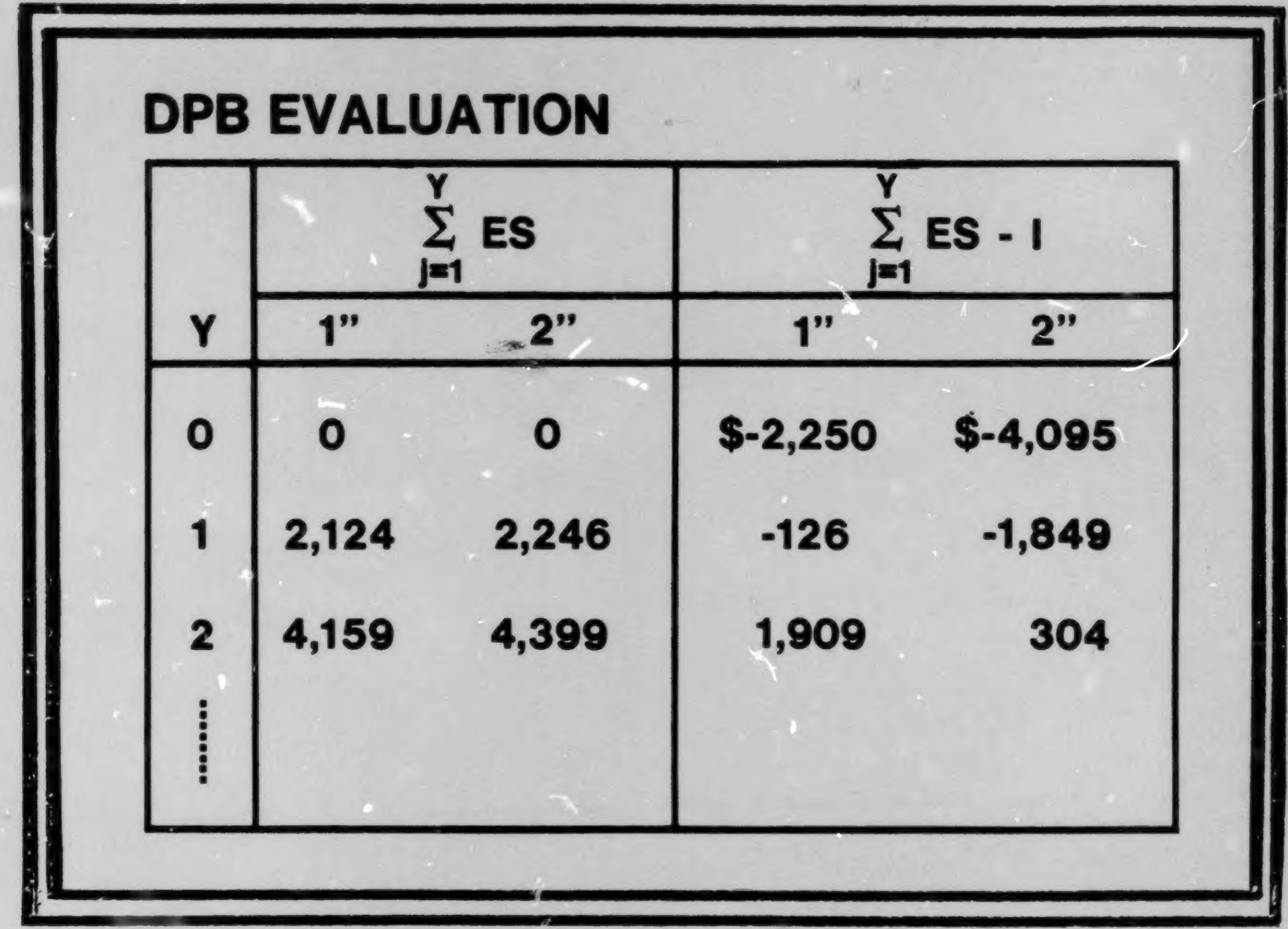
$$SIR_{2''} = \left[\frac{(150\text{-}12.5\ \text{Btu/hr/ft}) \cdot 1{,}040\ \text{hrs} \cdot 1{,}000\ \text{ft}}{0.55 \cdot 10^6\text{Btu}} \cdot \$9.00/10^6\text{Btu} \cdot 17.77\right] \div \$4{,}095$$

$$= 10.15$$

SIR Evaluation

- Go through the SIR evaluation.
- Ask what the results indicate.
- Point out the apparent contradiction between the sizing decision supported by NS and LCC and that supported by SIR.
- Tell them that we will return to that matter shortly.

Slide 12



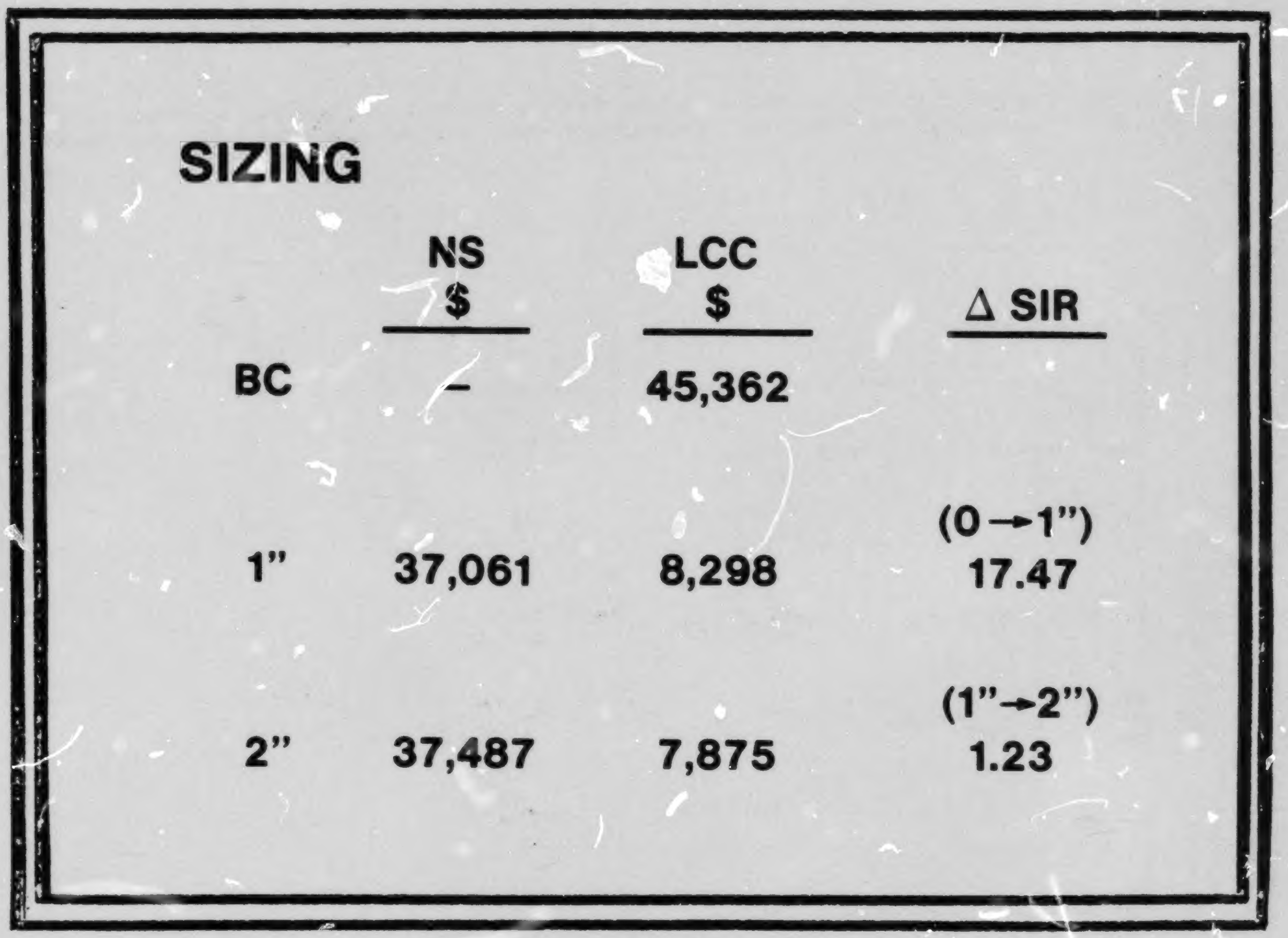
DPB EVALUATION

	$\sum_{j=1}^{Y} ES$		$\sum_{j=1}^{Y} ES - I$	
Y	1"	2"	1"	2"
0	0	0	\$-2,250	\$-4,095
1	2,124	2,246	-126	-1,849
2	4,159	4,399	1,909	304
⋮				

DPB Evaluation

- o Go through the DPB evaluation.
- o Ask what the results indicate.
- o Point out that the DPB indicates a sizing choice consistent with the SIR.

Slide 13



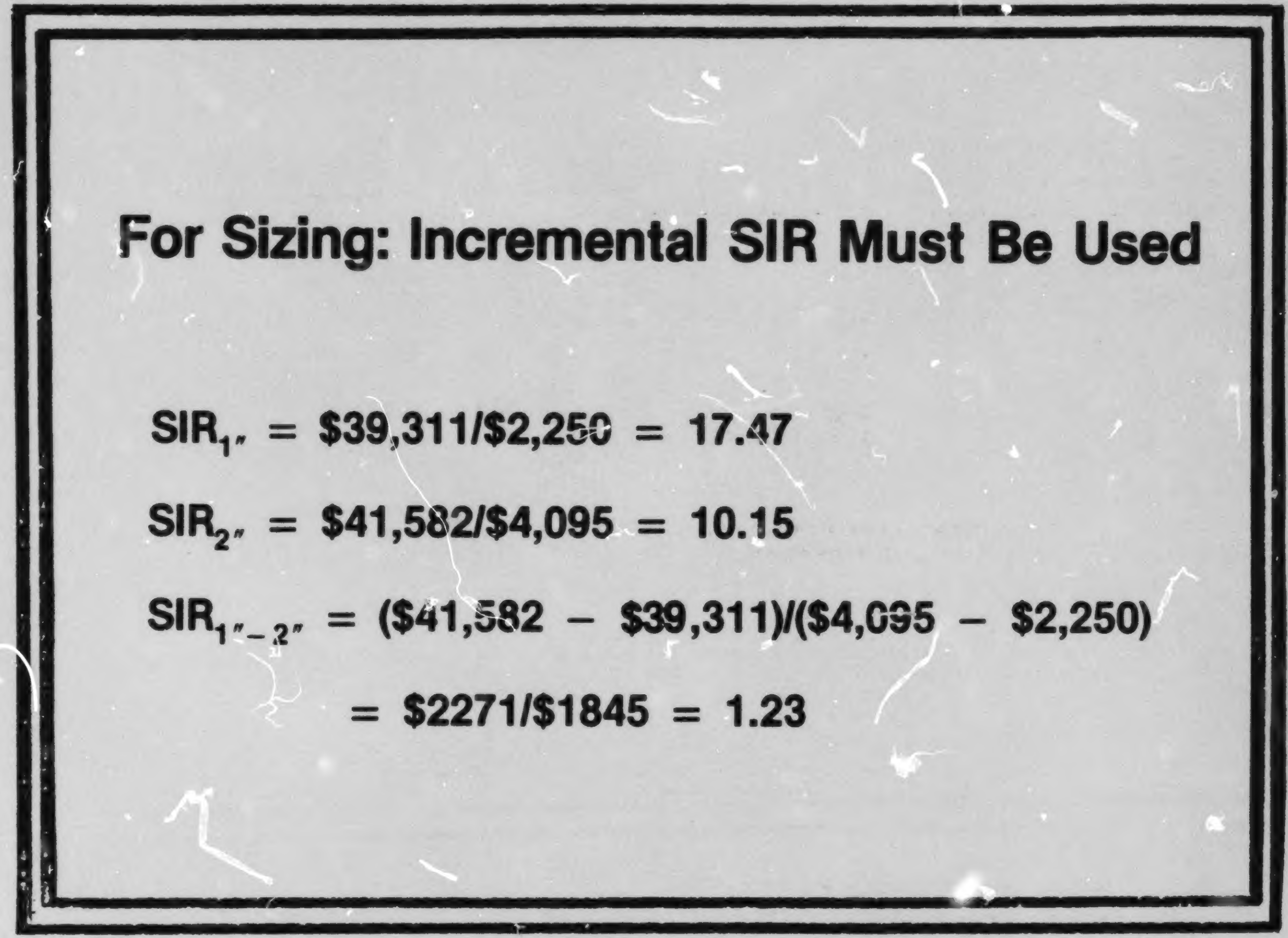
SIZING

	NS $	LCC $	Δ SIR
BC	–	45,362	
1"	37,061	8,298	(0 → 1") 17.47
2"	37,487	7,875	(1" → 2") 1.23

Sizing

- Now address the issue of sizing, referring the class to Step 7 in the Workbook solution.
- Note the change to an incremental SIR for sizing, explaining the deficiencies with using SIR's based on total values for sizing decisions.
- Note that the three methods are now in agreement as to the cost-effective thickness of insulation, if there is no budget constraint.

Slide 14



For Sizing: Incremental SIR Must Be Used

$$SIR_{1''} = \$39{,}311/\$2{,}250 = 17.47$$

$$SIR_{2''} = \$41{,}582/\$4{,}095 = 10.15$$

$$SIR_{1''-2''} = (\$41{,}582 - \$39{,}311)/(\$4{,}095 - \$2{,}250)$$

$$= \$2271/\$1845 = 1.23$$

For Sizing: Incremental SIR Must Be Used

- o Refer to and discuss material entitled "Incremental SIR (ΔSIR) Evaluation" in Workbook following Step 8.

Slide 15

RANKING

PROJECTS	SIR	PRIORITY
A (0 → 1" Insulation)	17.47	2
B (1 → 2" Insulation)	1.23	5
C	1.15	6
D	15.50	3
E	25.00	1
F	12.52	4
G	0.75	Not acceptable

Ranking

- Refer the class to Step 9 of the Workbook solution.
- Explain that you would like to present two alternative approaches and discuss the pros and cons of each.
- Explain and discuss the approach of simultaneously sizing and ranking projects.

Slide 16

RANKING

PROJECTS	SIR	PRIORITY
$\bar{A}$ (0→2" Insulation)	10.15	4
C	1.15	5
D	15.50	2
E	25.00	1
F	12.52	3
G	0.75	Not acceptable

Ranking

- Explain and discuss the approach of just sizing the project independent of other projects and the budget constraint and then ranking the project. (The relative merits of the two approaches are discussed briefly in the Workbook.)

Section 8

Programmable Time Clock Problem (40 Minutes)

The purposes of this problem are (1) to give the class their first solo experience in the seminar in calculating net savings and the SIR for a realistic investment, and (2) to give them practice using the worksheets supplied in the Manual. This is a "real-world" problem in that the building and conditions described are for a real building in Texas. The decision to buy a programmable time clock was based on the evaluation shown here.

Allow the class a couple of minutes to read the problem. Explain the purpose of the exercise as described above. Ask for questions. Have each of the class members proceed through the worksheets. Intervene after an appropriate work time between each worksheet to explain how the figures in the blanks were calculated. (Note the Remarks to Help the Class.) Encourage class participation by asking participants how they arrived at particular numbers.

Conclude the problem with an analysis of Net Savings and the SIR. Discuss with the class under what conditions the time clock would be cost effective with the computed SIR value. Answer any questions.

Programmable Time Clock Problem

Problem Statement: An energy-conserving retrofit is being considered for the Federal office and courthouse building in Houston, Texas (DoE Region 6). The remaining life of the building is expected to be 20 years or more.

At present, the building has a mechanical time clock that turns building HVAC equipment on and off. This clock runs all HVAC equipment during overtime hours. A programmable time clock could reduce after-hours equipment usage by turning on only needed HVAC equipment. It is estimated that the programmable clock would reduce by 80 percent the current after-hours electricity consumption of 323,220 kWh per annum.

The price of electricity to the agency is $0.0373 per kWh. The programmable clock would last for 20 years and cost $9,000 to purchase and install. There are no other sizable costs or salvage values associated with either clock.

Determine: Is the proposed time clock retrofit cost effective?

Programmable Time Clock

Remarks to Help the Class

Slide	
4	The UPW* factor of 12.92 is found on page 123, Table B-6, under N=20, for commercial buildings using electricity.
9	An 80% cut in electricity consumption will leave an annual consumption of 20% of the original 323,200 kWh (i.e., 64,644 kWh).

Slide 1

Problem Solving With LCC Worksheets

Slide 2

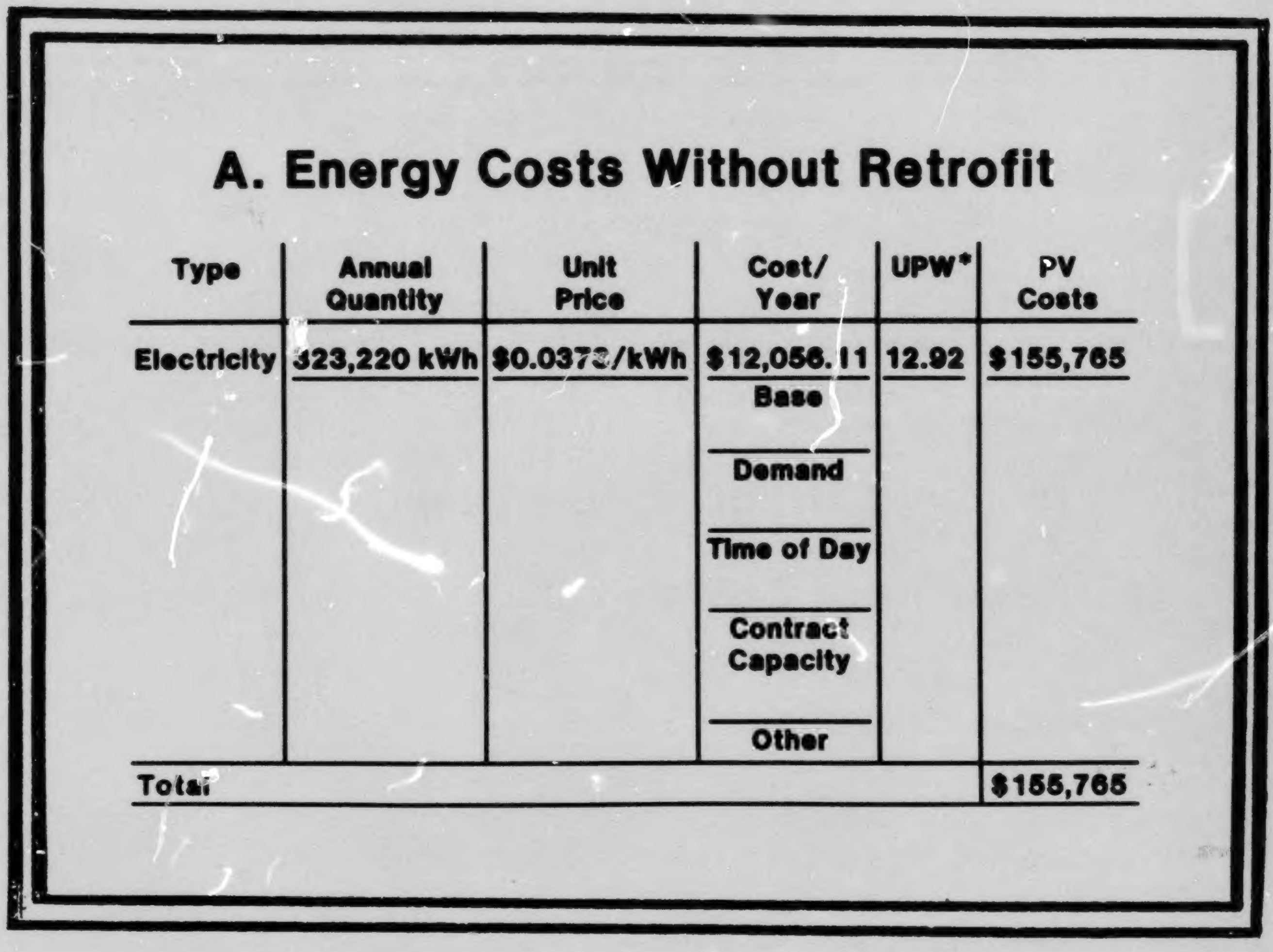
PROGRAMMABLE
TIME CLOCK PROBLEM

Slide 3

Identifying Information

Building:	
Location	Houston, Texas
DOE Region	6
Use	Offices and Courts
Type	Commercial
Life	20 Years or More
Project	Replace Time Clock
Project Life	20 Years
Study Period	20 Years

Slide 4



A. Energy Costs Without Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	323,220 kWh	$0.0373/kWh	$12,056.11	12.92	$155,765
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$155,765

Slide 5

B. Investment Costs Without Retrofit

(1) Resale, Salvage, Reuse Value	$0
(2) Renovation Costs	$0

Slide 6

C. Annual Nonfuel O&M Costs Without Retrofit

(1) Amount	(2) UPW	(3) PV Costs
$0	--	$0

Slide 7

D. Nonannual O&M, Replacement, and Salvage Without Retrofit

(1) Year	(2) O&M Costs	(3) Replacement Costs	(4) Salvage Value	(5) SPW	(6) PV O&M	(7) PV Replacement	(8) PV Salvage
Total					$0	$0	$0

Slide 8

E. TLCC Without Retrofit

(1) PV Energy	$155,765
(2) PV Investment	$ 0
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$155,765

Slide 9

F. Energy Costs With Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	64,644 kWh	$0.0373/kWh	$2,411.22	12.92	$31,153
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$31,153

Slide 10

G. Investment Costs With Retrofit

(1) Actual Costs	$9,000
(2) Adjustment Factor	0.9
(3) Adjusted Costs	$8,100
(4) Renovation Costs	$ 0
(5) Adjusted PV	$8,100

H. Annual Nonfuel O&M Costs With Retrofit

(1) Amount	(2) UPW	(3) PV Costs
$0	–	$0

Slide 12

I. Nonannual O&M, Replacement, and Salvage With Retrofit

(1) Year	(2) O&M Costs	(3) Replacement Costs	(4) Salvage Value	(5) SPW	(6) PV O&M	(7) PV Replacement	(8) PV Salvage
Total					$0	$0	$0

Slide 13

J. TLCC With Retrofit

(1) PV Energy	$31,153
(2) PV Adjusted Investment	$ 8,100
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$39,253

Slide 14

K. Net Savings of Project

(1) TLCC Without	$155,765
(2) TLCC With	$ 39,253
(3) Net Savings	+$116,512

Slide 15

L. SIR

(1)	**Numerator**	
	(a) Δ Energy Cost	$124,612
	(b) Δ Nonfuel O&M	$ 0
	(c) Numerator	$124,612
(2)	**Denominator**	
	(a) Δ Investment	$ 8,100
	(b) Δ Replacement	$ 0
	(c) Δ Salvage	$ 0
	(d) Denominator	$ 8,100
(3)	**SIR**	15.38

Section 9

Backup Problem: New Building Design Problem (25 Minutes)

Time permitting, this problem can be presented at the end of Day 1. The problem illustrates how life-cycle costs of alternative building designs can be used to calculate the present value of net savings from choosing one design over another. It also illustrates that, among designs very close in life-cycle costs, there may still be a strong economic argument for selecting one over another.

Allow the class a few minutes to read the problem. Explain the purpose of the exercise as described above. Emphasize that the two designs are equivalent in space and functional performance, and that the primary criterion for comparison in this problem is the comparative life-cycle costs. Ask for any questions.

Have the class members proceed individually through the work sheets. Suggest that the figures for each of the two designs be placed in one set of worksheets, listing numbers for the energy-conserving design first, and listing in parentheses numbers for the conventional design directly beneath them. Intervene after an appropriate work time between each worksheet to explain how the figures were calculated. Ask for volunteers to describe how they arrived at their numbers before explaining the computations.

Elaborate on how to evaluate the project with the net savings and SIR techniques when discussing the TLCC summary schedule, slide 6. (See Remarks to Help the Class, Slide 7.)

Conclude by summarizing the purpose of the problem and asking for any questions.

New Building Design Problem

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: An energy-conserving building design is being considered as an alternative to a conventional building design for a Federal office building in Madison, Wisconsin (DoE Region 5). The two designs are approximately equivalent in total assignable and auxiliary spaces and in functional performance with respect to the purpose of the building. Each has two underground levels for parking and seven office floors, plus a mechanical house. Each has a floor area of approximately 176,000 ft^2 (gross).

The two designs differ primarily in the envelope, building configuration, orientation, and lighting systems. The energy-conserving design is slightly elongated on the east-west axis for greater exposure of the south side to solar radiation. The window area of the energy-conserving design is 25 percent of the wall area and most of that is located on the south side; in the conventional building, it is 40 percent. More massive exterior surfaces are used and insulation is increased, reducing the wall U value from 0.16 to 0.06, and the roof U value from 0.15 to 0.06. Horizontal window fins reduce the summer cooling load of the energy-conserving design. The north wall of the first floor of the energy-conserving design is earth bermed. It is assumed that both designs will last at least 25 years, and, for lack of a good basis for projecting differences in their salvage values, they are both assumed to have no salvage value remaining at the end of the 25-year study period.

Following is a listing of the major relevant costs for each design:

	Energy-Conserving Design	Conventional Design
(a) Site acquisition costs: (To ensure adequate exposure of south-facing windows, an additional acquisition cost of $100,000 is necessary for the energy-conserving design. Other site costs are assumed to be identical for both designs, and hence are not shown.)	$100,000	
(b) Architectural and Engineering Design Fees and Construction Costs:	$9,780,000	$9,130,000
(c) Annual Energy Consumption:		
Natural Gas	$2,290 \times 10^6\text{Btu}$	$4,980 \times 10^6\text{Btu}$
Electricity	$3,866 \times 10^6\text{Btu}$	$7,277 \times 10^6\text{Btu}$
(d) DoE Energy Prices:		
Natural Gas	$\$\ 3.84/10^6\text{Btu}$	$\$\ 3.84/10^6\text{Btu}$
Electricity	$15.67/10^6\text{Btu}$	$15.67/10^6\text{Btu}$
(e) Nonfuel O&M Costs:		
Recurring Annual Cost:	$70,000	$90,000
Repairs to External Surfaces Every 10 Years:	$60,000	$100,000

Which design has the lowest life-cycle cost?

New Building Design Problem

Remarks to Help the Class

Slide Number   Slide Title

4   Investment Costs

The energy conserving design has an actual cost of $9,880,000, the sum of $100,000 in site acquisition costs and $9,780,000 in design fees and construction costs.

Note that the differential investment costs ($9,880,000-$9,130,000 = $750,000) represent investment costs for energy conservation and therefore are subject to the .9 adjustment factor. Multiplying actual costs for each design in Slide 3 by .9 and entering those adjusted values in line 2 of slide 6 is mathematically equivalent to adjusting the $750,000 extra costs for conservation by .9. Either method adds to the TLCC with energy conservation an adjusted investment of $675,000.

6   Nonannual, O&M, Replacment, and Salvage

Repair costs that occur every 10 years are discounted to present value with the SPW factors found on page 114 of HB 135, for N=10 and N=20.

Slide Number	Slide Title	Remarks to Help the Class
7	TLCC	

After discussing the figures shown on slide 6, ask the group what net savings would be. Subtracting TLCC of the energy conservation design from the TLCC without the conservation design (i.e., of the conventional design) gives a net savings of $542,355.

Ask the group if the net savings justify the extra first costs for the energy conserving design. Whereas the TLCC of the two designs are very close, point out that the total savings ($1,217,355) generated by the energy design from reductions in energy costs ($953,555), annual O&M costs ($233,000), and nonannual O&M costs ($30,800) are substantially more than the extra investment ($675,000, adjusted) required to generate them. Thus, a SIR of 1.8 ($1,217,355 ÷ $675,000) suggests the energy conserving design is quite cost effective, assuming no budget constraints are binding.

Slide 1

NEW BUILDING DESIGN PROBLEM

Slide 2

Identifying Information

Building:

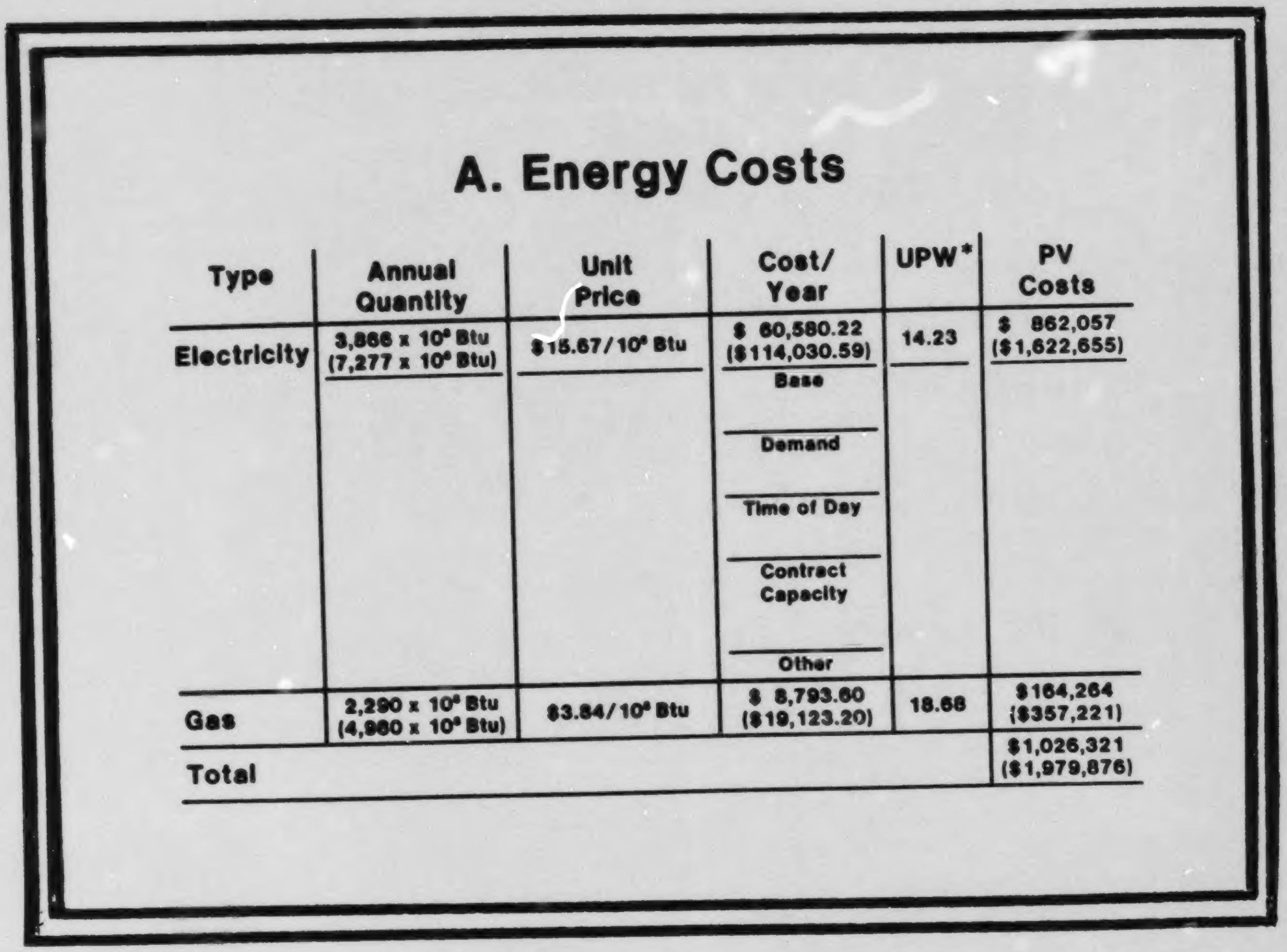
- Location: Madison, Wisconsin
- DOE Region: 5
- Use: Offices
- Type: Commercial

Project: Energy-Conserving Design

Project Life: At Least 25 Years

Study Period: 25 Years

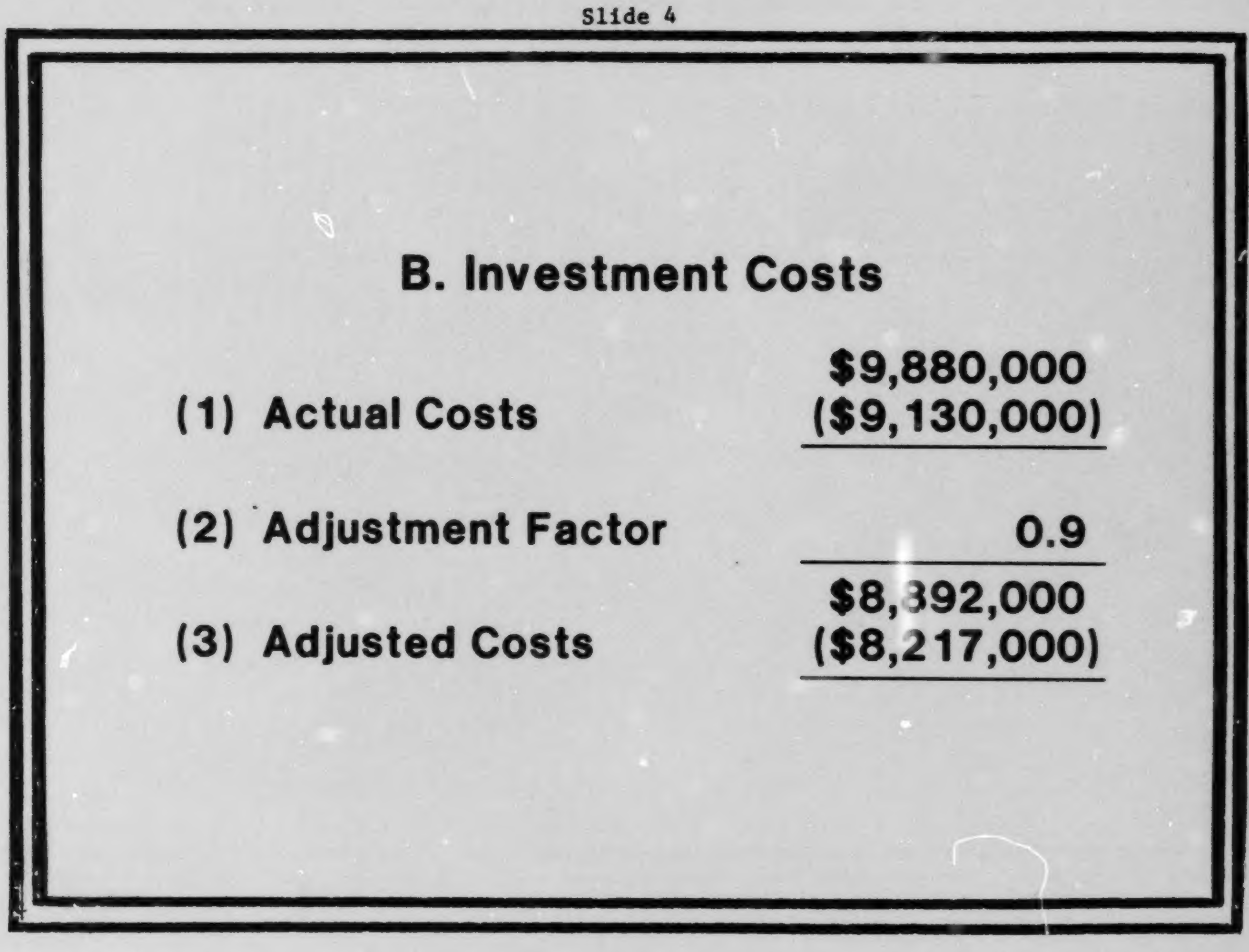
Slide 3



A. Energy Costs

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	3,866 x 10^6 Btu (7,277 x 10^6 Btu)	$15.67/$10^6$ Btu	$ 60,580.22 ($114,030.59) Base Demand Time of Day Contract Capacity Other	14.23	$ 862,057 ($1,622,655)
Gas	2,290 x 10^6 Btu (4,960 x 10^6 Btu)	$3.84/$10^6$ Btu	$ 8,793.60 ($19,123.20)	18.68	$164,264 ($357,221)
Total					$1,026,321 ($1,979,876)

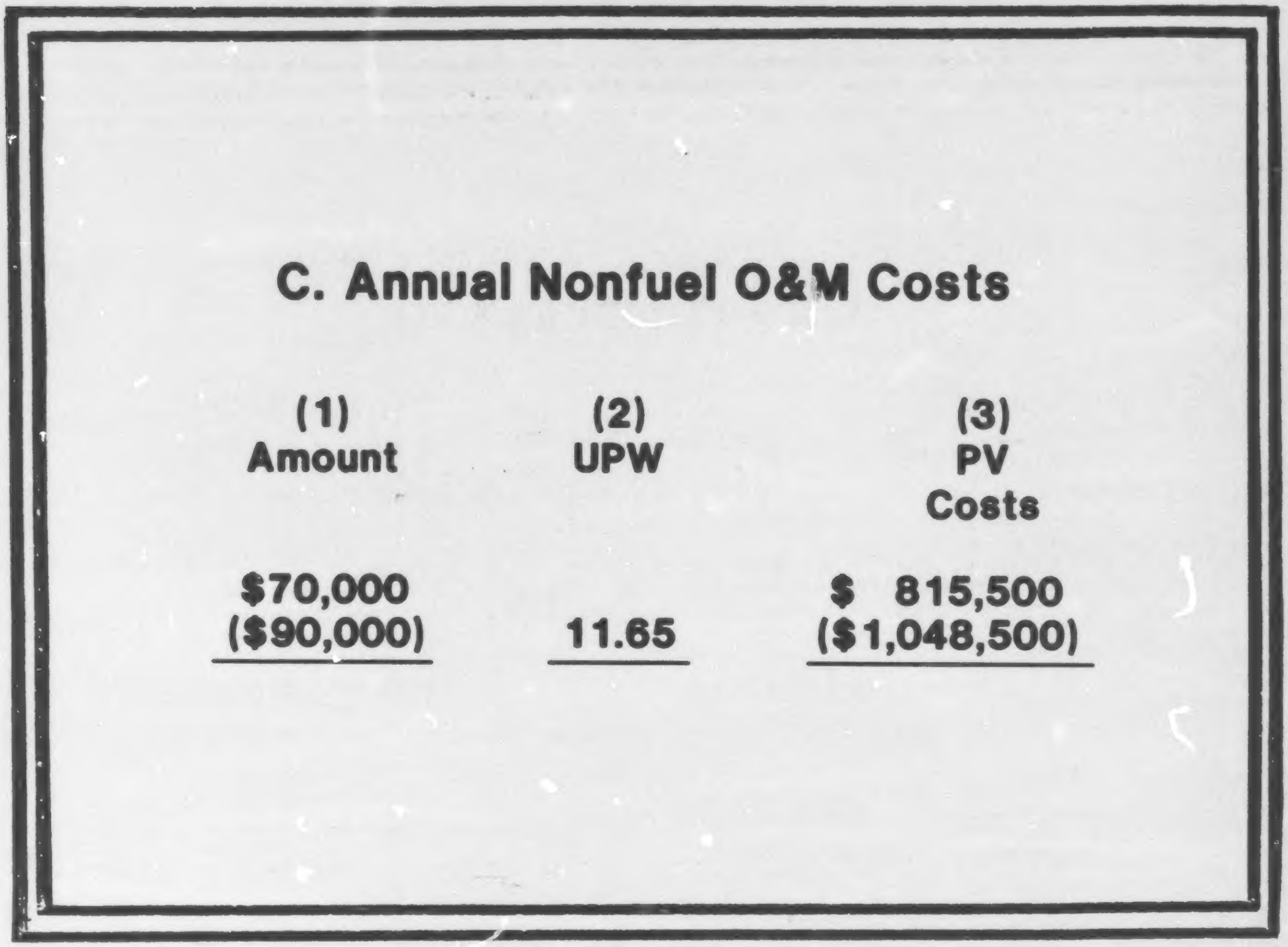
Slide 4



B. Investment Costs

(1) Actual Costs	$9,880,000 ($9,130,000)
(2) Adjustment Factor	0.9
(3) Adjusted Costs	$8,892,000 ($8,217,000)

Slide 5



C. Annual Nonfuel O&M Costs

(1) Amount	(2) UPW	(3) PV Costs
$70,000		$ 815,500
($90,000)	11.65	($1,048,500)

Slide 6

D. Nonannual O&M, Replacement, and Salvage

(1) Year	(2) O&M Costs	(3) Replacement Costs	(4) Salvage Value	(5) SPW	(6) PV O&M	(7) PV Replacement	(8) PV Salvage
10	$ 60,000 ($100,000)			0.51	$30,600 ($51,000)		
20	$ 60,000 ($100,000)			0.26	$15,600 ($26,000)		
Total					$46,200 ($77,000)	$0	$0

Slide 7

E. TLCC

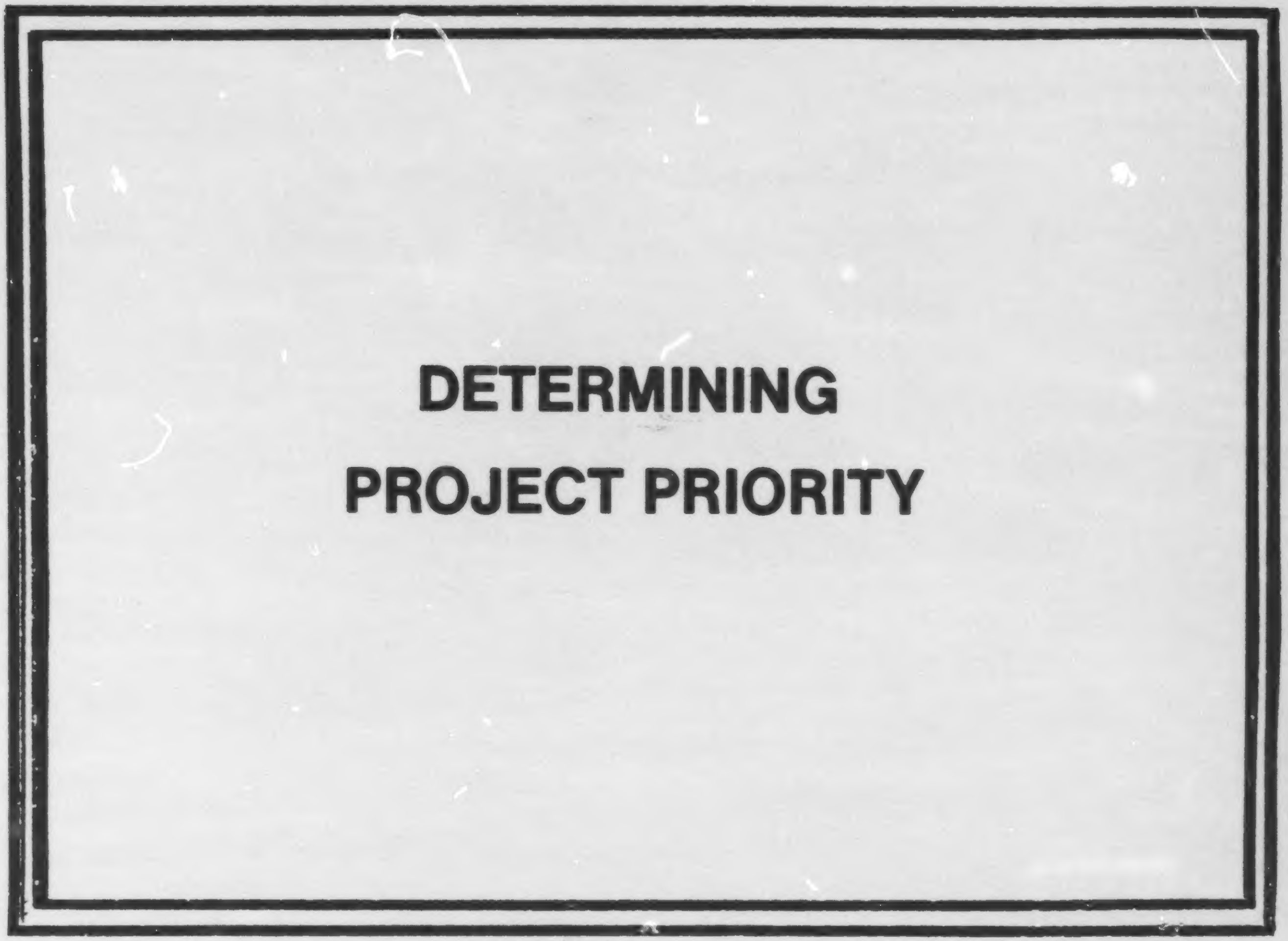
(1) PV Energy	$ 1,026,321 ($ 1,979,876)
(2) PV Investment	$ 8,892,000 ($ 8,217,000)
(3) PV Annual O&M	$ 815,500 ($ 1,048,500)
(4) PV Nonannual O&M	$ 46,200 ($ 77,000)
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$10,780,021 ($11,322,376)

Section 10

Slide Presentation: Determining Project Priority: A Comparison of Ranking Methods (20 minutes)

The purposes of this session are to (1) describe how to use the SIR method to select the combination of projects that will maximize total net savings for a limited budget and to (2) demonstrate that the SIR method is the best ranking method in evaluating projects when the objective is to achieve the maximum net savings or net benefits for a limited budget. The SIR method's superiority over the "10^6 Btu/$1000 of investment" (Btu/I) method and the Net Savings (NS) method is illustrated by using each of the three methods to select among four projects competing for a limited budget and then computing the NS for each package of projects.

Slide 1

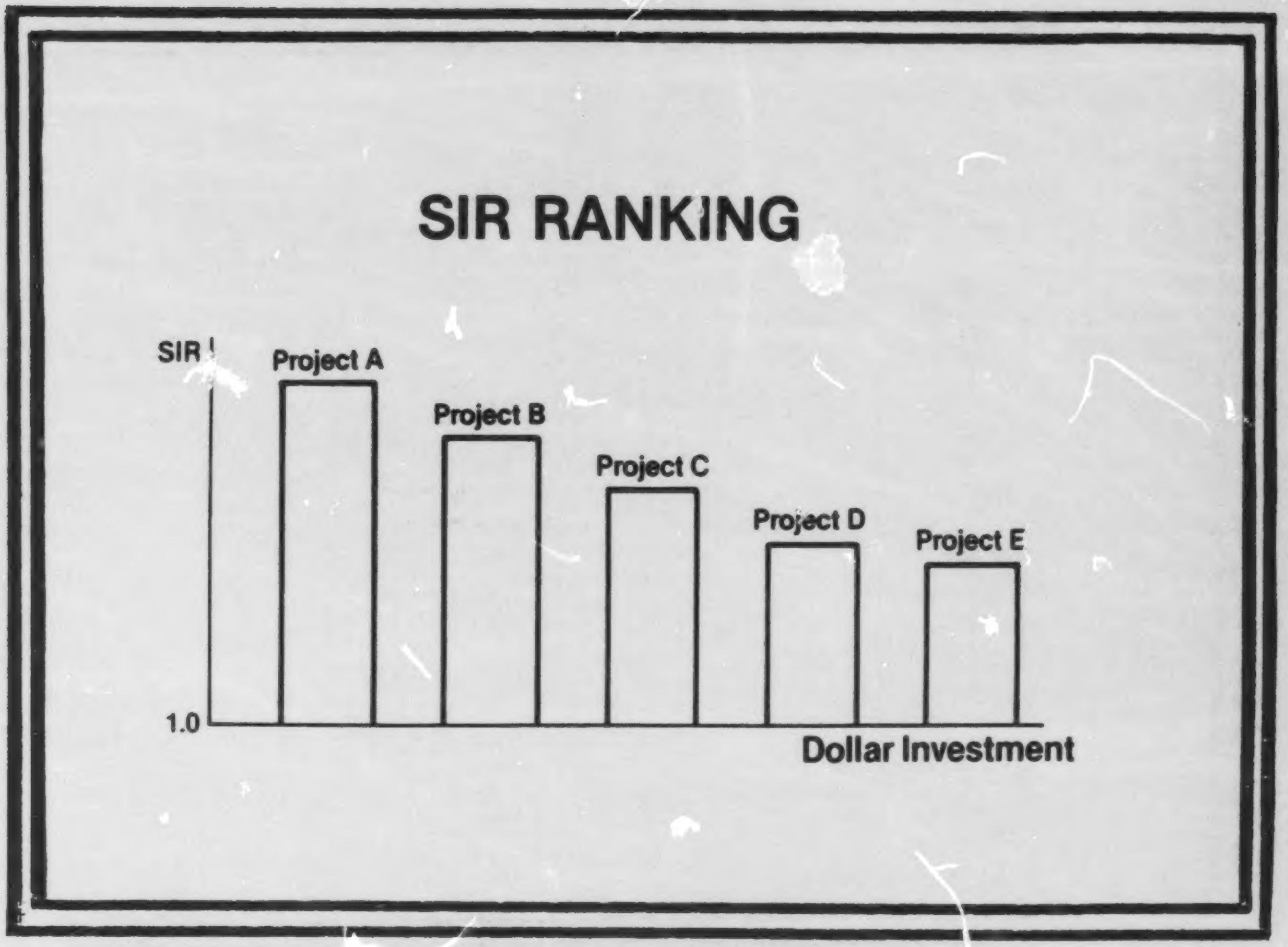


DETERMINING
PROJECT PRIORITY

Determining Project Priority

- o Present the introduction.

Slide 2

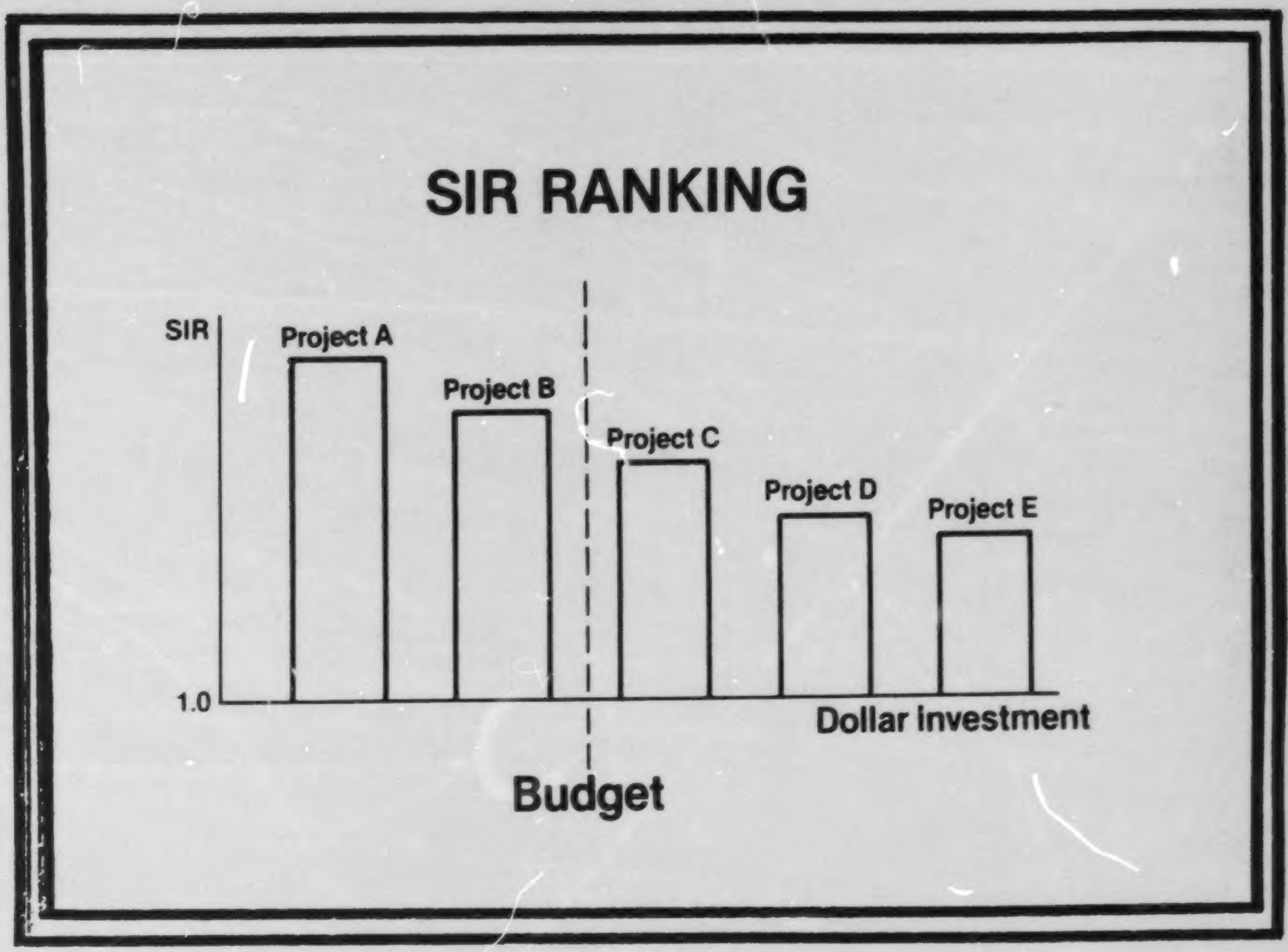


SIR RANKING

SIR Ranking Bar Chart

- Describe the bar chart. Give examples of the types of projects that might be represented.
- Explain why the SIR method is recommended for establishing priority when the budget is limited.
- Note that SIR is recommended for the FEMP.

Slide 3

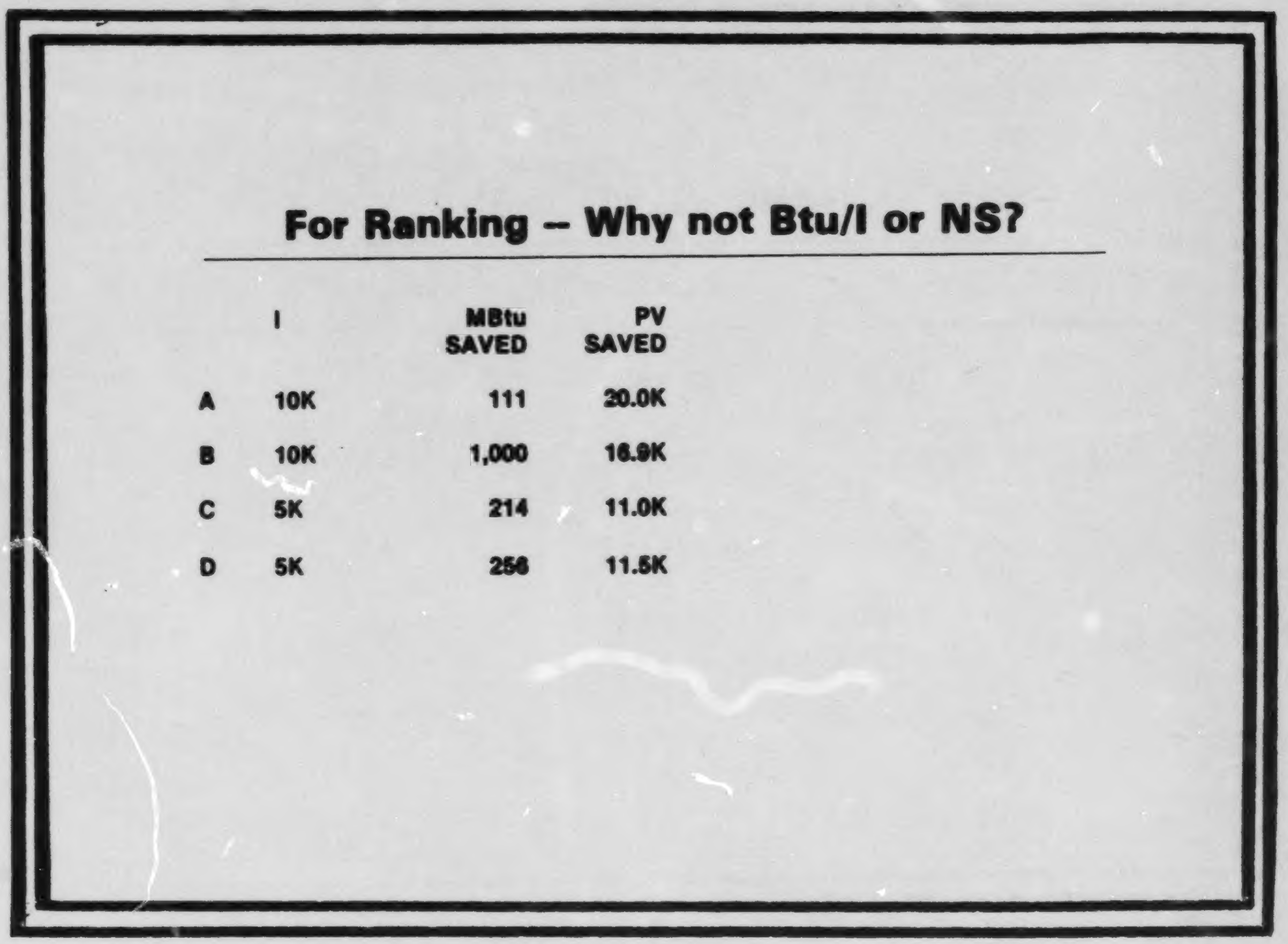


SIR RANKING

SIR Ranking

- Explain the budget line.
- Describe the implications of budget shifts.

Slide 4



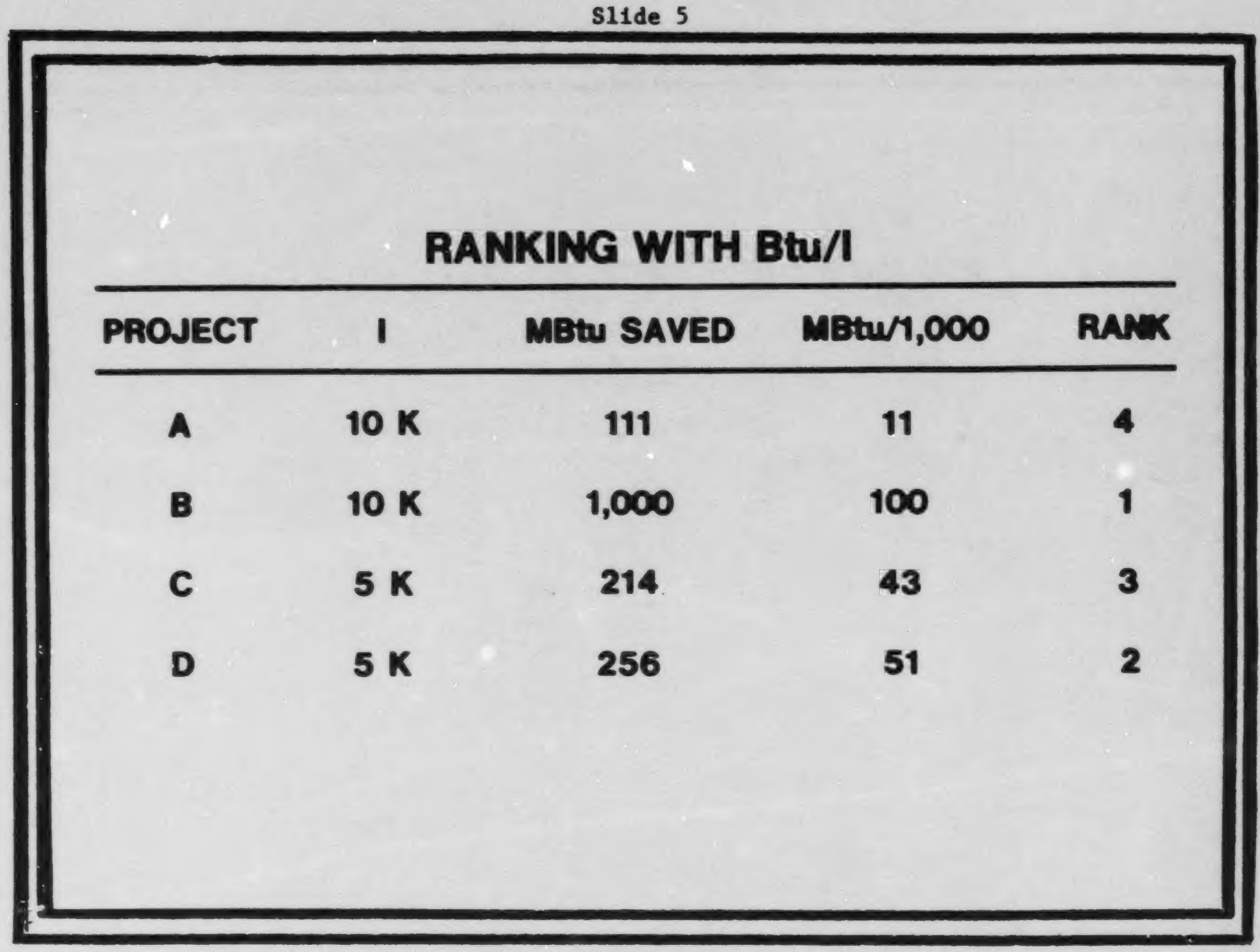
For Ranking -- Why not Btu/I or NS?

	I	MBtu SAVED	PV SAVED
A	10K	111	20.0K
B	10K	1,000	16.9K
C	5K	214	11.0K
D	5K	256	11.5K

Why Not Btu/I or NS?

- Describe the Btu/I and NS measures.
- Explain the table figures.
- Ask the class if anything is peculiar about projects A and B. Discuss how these MBtu and PV savings figures would result if A were expensive electricity and B were cheap coal.
- Assign priority on the basis of these two measures.

Slide 5



RANKING WITH Btu/I

PROJECT	I	MBtu SAVED	MBtu/1,000	RANK
A	10 K	111	11	4
B	10 K	1,000	100	1
C	5 K	214	43	3
D	5 K	256	51	2

Ranking With Btu/I

- Explain how MBtu/$1,000 column is derived.
- Show in table how project B that saves a lot of fuel (whether expensive or not) scores high with this measure.

Slide 6

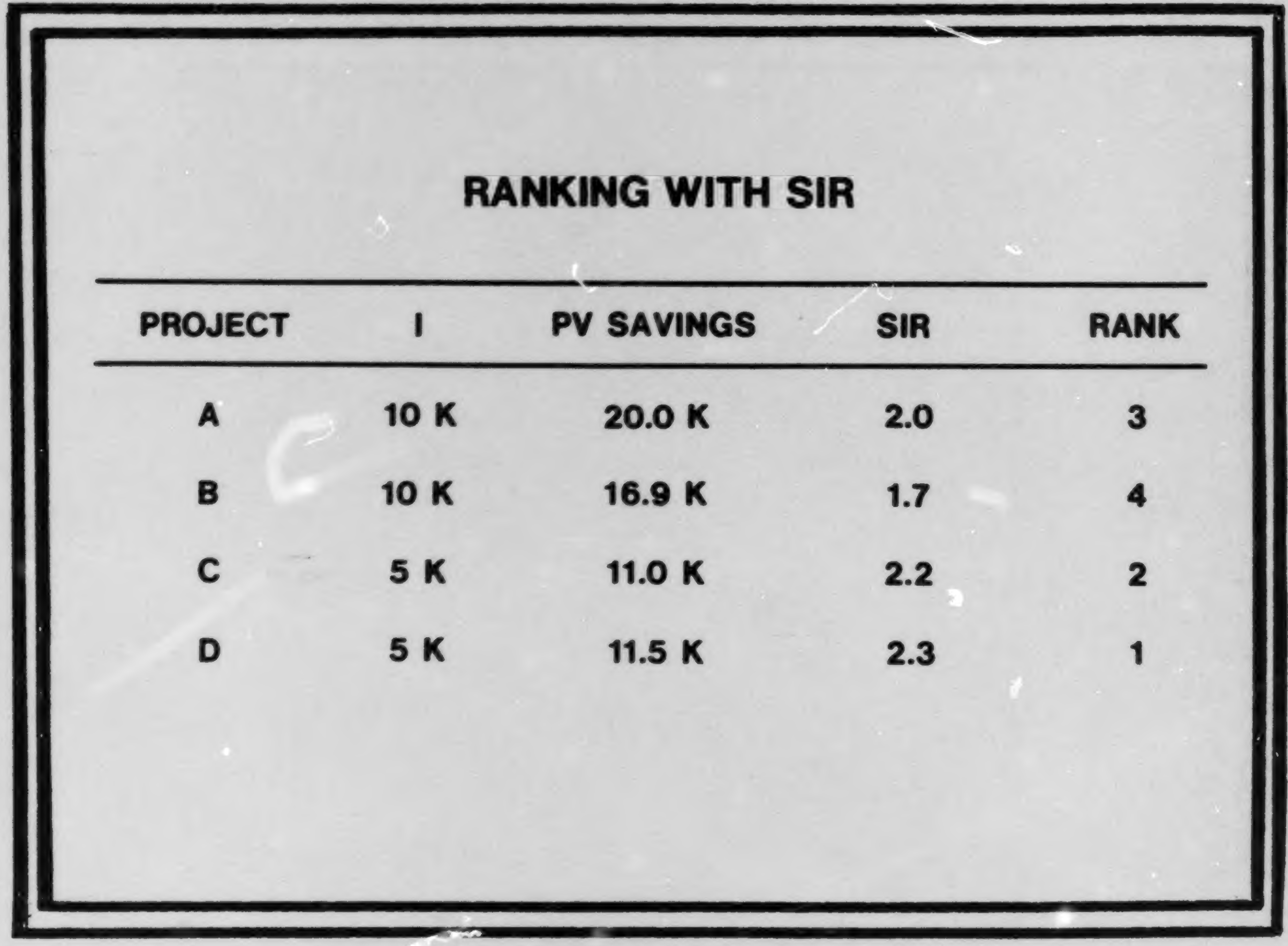
RANKING WITH NET SAVINGS

PROJECT	I	PV SAVINGS	NS	RANK
A	10 K	20.0 K	10.0 K	1
B	10 K	16.9 K	6.9 K	2
C	5 K	11.0 K	6.0 K	4
D	5 K	11.5 K	6.5 K	3

Ranking With Net Savings

- Explain the derivation of the NS ranking.
- Explain why project A saving high-priced fuel now rates highest.

Slide 7



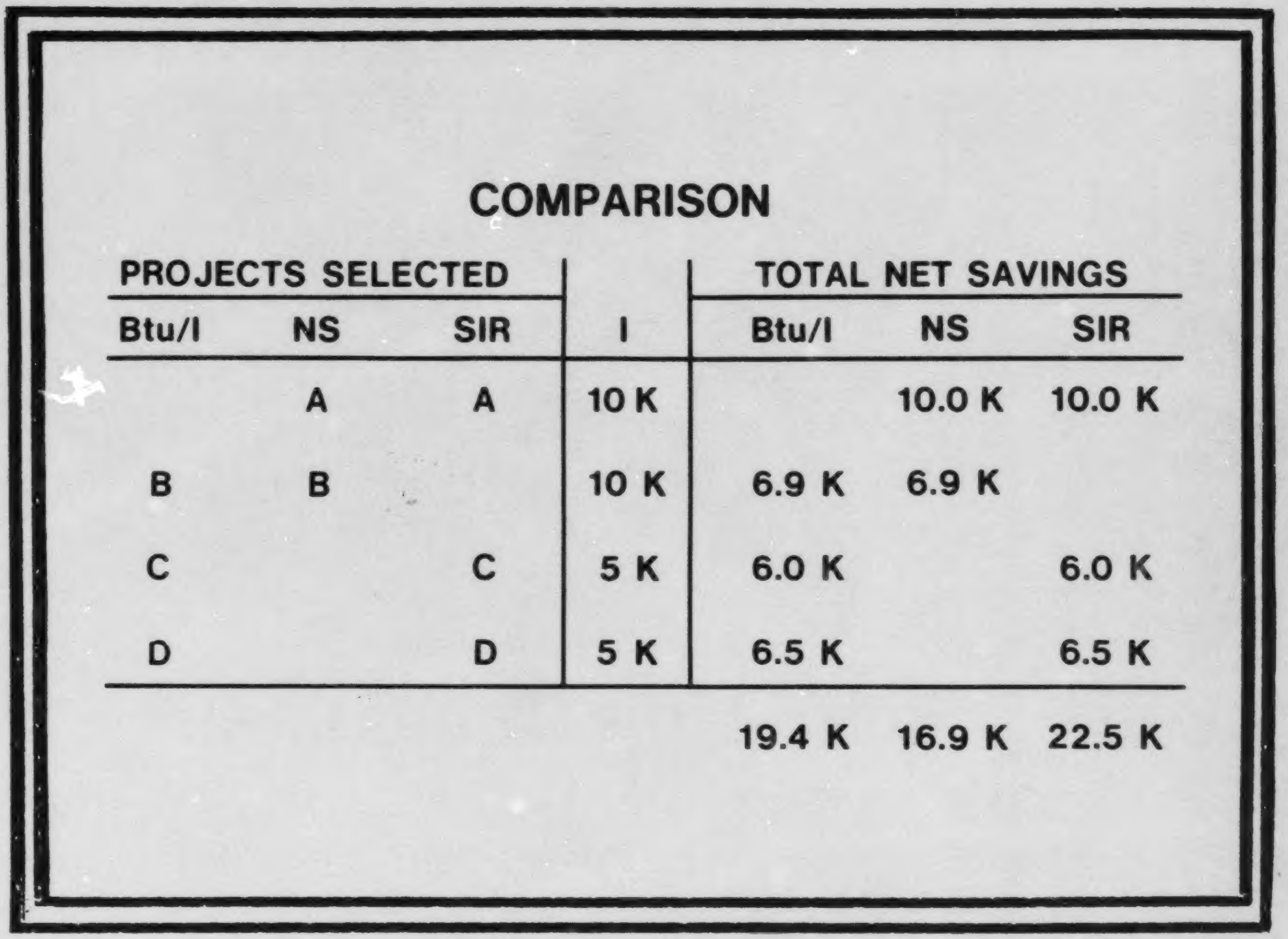
RANKING WITH SIR

PROJECT	I	PV SAVINGS	SIR	RANK
A	10 K	20.0 K	2.0	3
B	10 K	16.9 K	1.7	4
C	5 K	11.0 K	2.2	2
D	5 K	11.5 K	2.3	1

Ranking with SIR

- o Explain the derivation of the SIR ranking.
- o Note that the rankings differ from each of the other two approaches.

Slide 8



COMPARISON

PROJECTS SELECTED				TOTAL NET SAVINGS		
Btu/I	NS	SIR	I	Btu/I	NS	SIR
	A	A	10 K		10.0 K	10.0 K
B	B		10 K	6.9 K	6.9 K	
C		C	5 K	6.0 K		6.0 K
D		D	5 K	6.5 K		6.5 K
				19.4 K	16.9 K	22.5 K

Comparison

- Tell the class that the table is designed to compare the three methods in terms of the net savings to be achieved with a $20K budget.
- Explain that the projects selected under each of the three ranking methods is based on their rankings and what is affordable with $20K.
- Explain that total net savings are computed for each package of projects indicated by the respective rankings.
- Note that NS are maximized for the package selected by the SIR ranking.
- Emphasize that the SIR method is generally preferred because it maximizes net savings when there is a budget constraint.
- Acknowledge, however, that other objectives might require consideration of other measures, e.g., the MBtu/$1,000 measure.

Section 11

Problem: Water Conservation Problem

The purposes of this problem are (1) to introduce the analysis of multiple elements of savings--energy and water, (2) to demonstrate the use of a multi-component charge structure for energy, and (3) to provide practical experience in project ranking under a budget constraint.

Allow about five minutes for the class to read the problem. Then explain the objectives of the problem as described above. Ask for suggestions regarding the study period. Discuss the merits of 5 years versus 25 years. Point out that there are two components to the energy charge: the demand component and the consumption component. Also note that the water consumption amount and the demand charge are given on a monthly basis and must be adjusted to an annual basis before entering the amounts in the worksheets. Ask about the selection of a UPW* factor. Note that it is based on natural gas. Also note that the same UPW* factor should be used to adjust the consumption and demand components of the energy costs to a present value basis. Ask the class to proceed through the worksheets. Allow time for completion of each worksheet, then explain how the blanks should be filled in. Note the following additional comments that pertain to certain of the schedules.

Notes

Schedule A

Annual demand charge = 20.21bs/hr X $.09/1b/hr/mo. X 12 mo/yr = $21.82.

Schedule C

Annual water consumption charge = 28,056 gals/mo X 12 mo/yr

X $0.65/1000 gals = $218.84.

Schedule F

Annual demand charge = 14.2 lbs/hr X $.09/1b/hr/mo X 12 mo/yr = $15.34.

Schedule G

Annual investment cost = ($7.00/showerhead X 8 showers) + ($1.14/aerator

X 105 faucets) = $175.70.

Schedule H

Annual water consumption charge = 28,056 gals/mo X 0.70 X 12mo/yr

X $0.65/1000 gals = $153.19.

Schedule L

Note that item (b), the change in water consumption cost, is reduced by the investment. Hence, using the worksheets format, a negative value is subtracted from item (a), that is, the two amounts are added.

After the SIR is calculated, review the last part of the problem with the class. Suggest that they use a tabular format to solve the problem. Ask them to indicate whether they recommend inclusion of the water conservation project and the maximum net savings they hope to realize.

Problem Selection - Limited Budget

Discuss the options that are within the budget, and compare their net savings.

Water Conservation Problem

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: A Federal office and courthouse building is part of the Oklahoma City Federal Complex in Oklahoma City, Oklahoma. It is expected to be continued in use indefinitely. An energy-conserving retrofit has been proposed.

Data and Assumptions: Currently, water consumption of the 8 showers and 105 faucets in the building totals 28,056 gallons per month. It is estimated that by installing flow restricting showerheads and faucet aerators on these fixtures, water consumption would decrease by 30 percent. In addition, these devices would reduce the quantity of steam required for heating water, since less would be heated. It is estimated that steam consumption of the fixtures would be lowered from 60,583 to 42,408 pounds per year, and the maximum hourly consumption rate of 20.2 pounds per hour would be reduced to 14.2 pounds per hour.

The local water utility charges the agency $0.65 per 1000 gallons of consumption. The purchased steam (produced from natural gas) has two separate charge components: (1) $0.0049 per pound of consumption, and (2) a monthly charge of $0.09 per pound per hour for the maximum hourly consumption rate. The flow restricting showerheads would cost $7.00 each, and the faucet aerators $1.14 each. It is assumed that there are no other significant costs or salvage values associated with these devices. Both devices are expected to last for 5 years.

There is a limited sum of $10,000 that has been budgeted for the retrofit of the building. Other retrofit project opportunities are as follows:

(1) A group of small projects, R, S, T, and U, costing a total of $2,000 and saving a total of $10,000 in present value dollars.
(2) Project V, having a first cost of $1,600 and a total present value saving of $12,000.
(3) Project W, having a first cost of $10,000 and a total present value saving of $80,000.
(4) Project X, having a first cost of $2,000 and a total present value saving of $25,000.
(5) Project Y, having a first cost of $3,000 and a total present value saving of $36,000.
(6) Project Z, having a first cost of $1,000 and a total present value saving of $9,000.

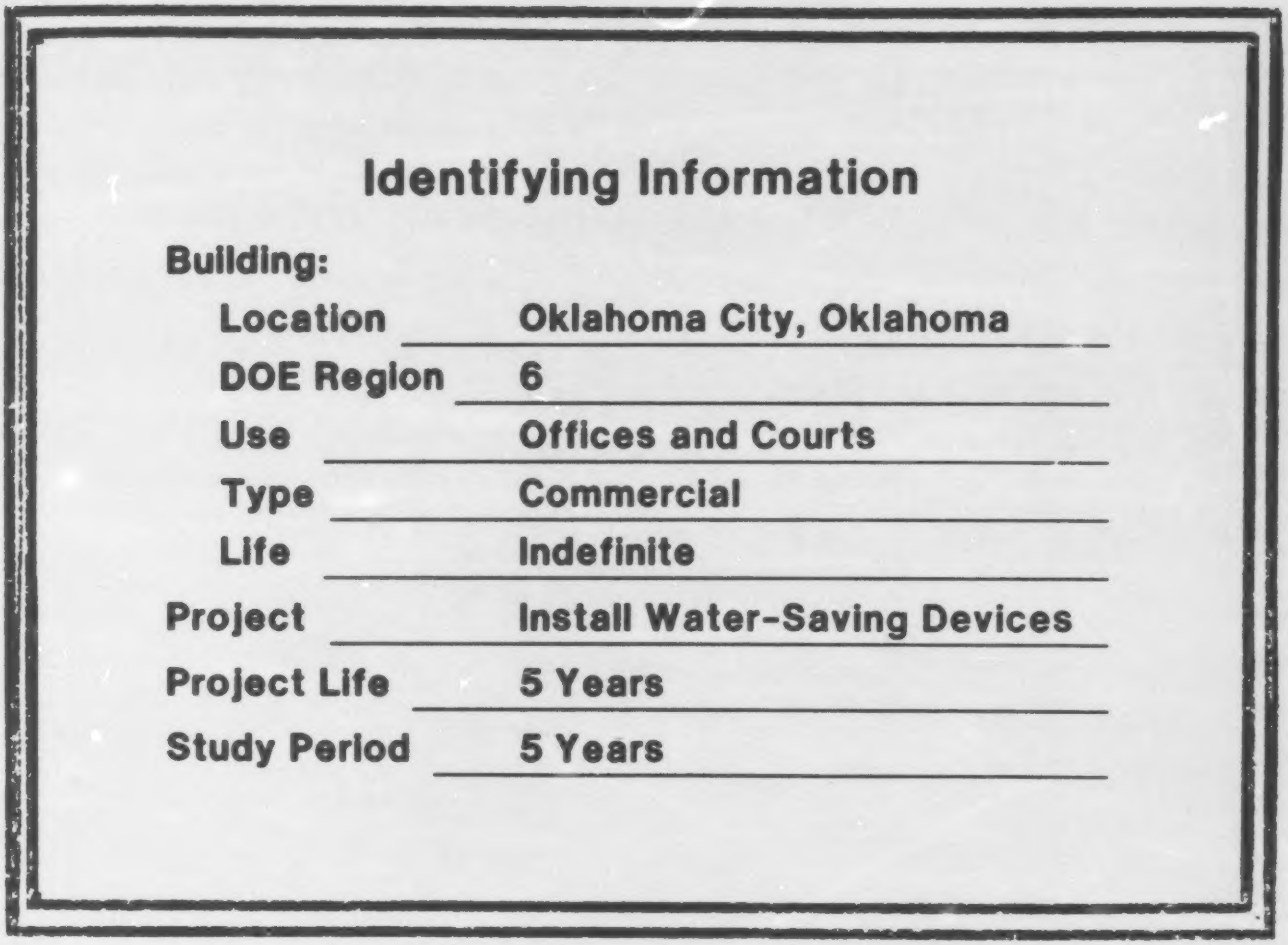
(Note: Assume 10% adjustment factor to investment costs does not apply to projects R-Z.)

Determine: Is the proposed water conservation retrofit cost effective? Do you recommend that the water conservation project be included in the projects funded by the $10,000 budget?

Slide 1

WATER CONSERVATION PROBLEM

Slide 2



Identifying Information

Building:

Location Oklahoma City, Oklahoma

DOE Region 6

Use Offices and Courts

Type Commercial

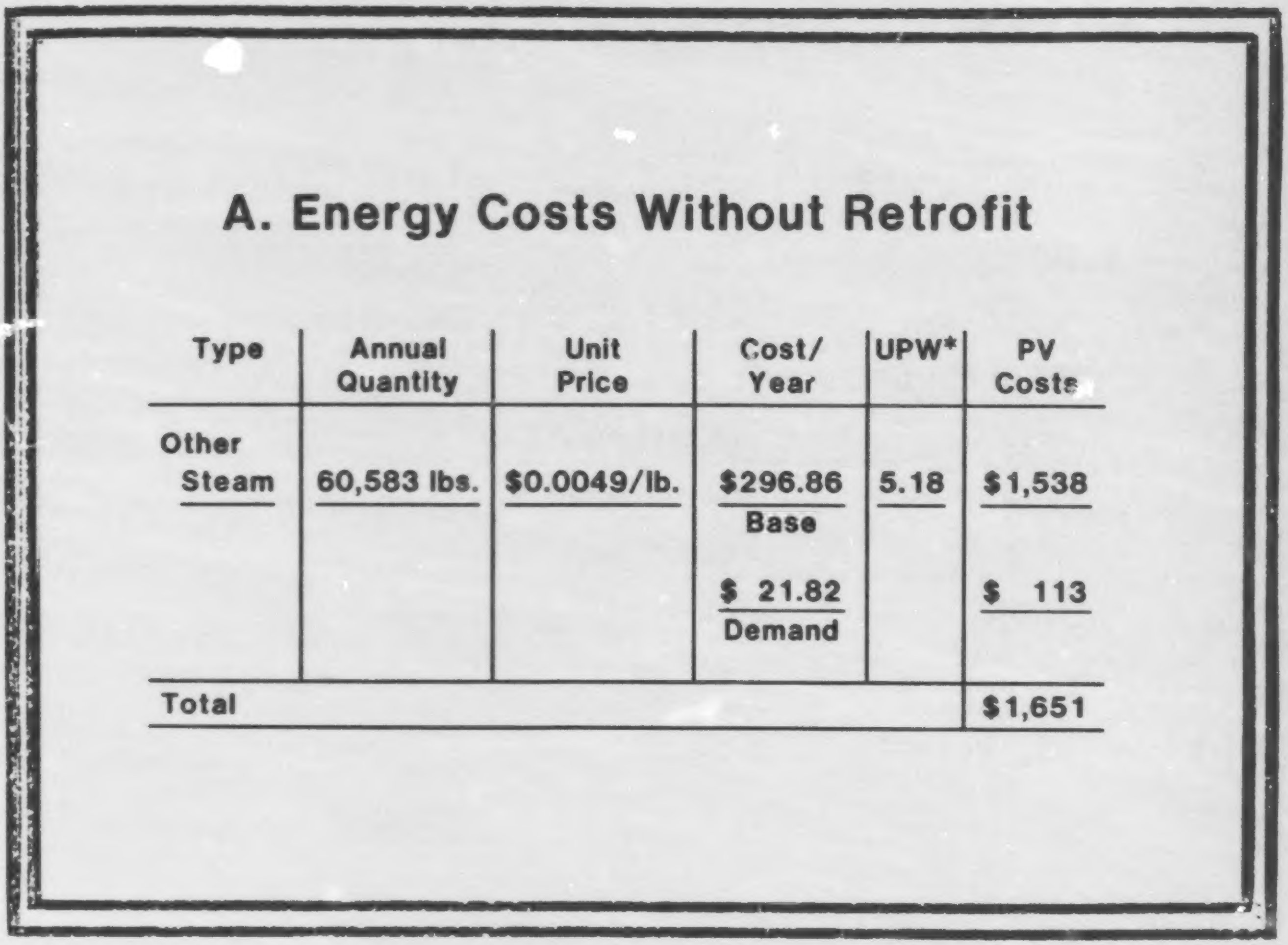
Life Indefinite

Project Install Water-Saving Devices

Project Life 5 Years

Study Period 5 Years

Slide 3



A. Energy Costs Without Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Other Steam	60,583 lbs.	$0.0049/lb.	$296.86 Base	5.18	$1,538
			$ 21.82 Demand		$ 113
Total					$1,651

B. INVESTMENT COSTS WITHOUT RETROFIT

1. RESALE, SALVAGE, REUSE VALUE	0
2. RENOVATION COSTS	0

Slide 5

C. Annual Nonfuel O&M Costs Without Retrofit

(1) Amount	(2) UPW	(3) PV Costs
$218.84	4.10	$897.00

Slide 6

D. Nonannual O&M, Replacement, and Salvage Without Retrofit

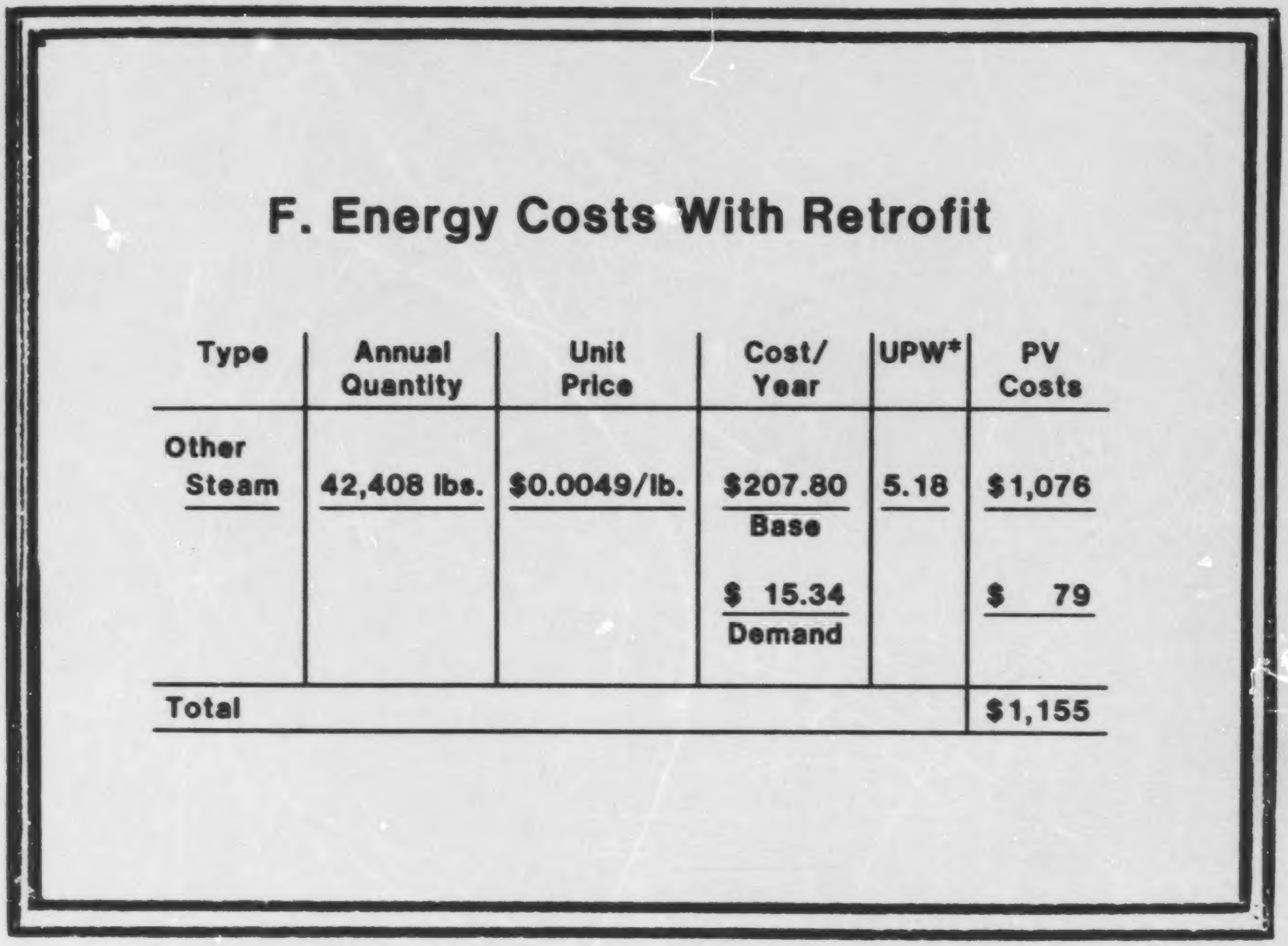
(1) Year	(2) O&M Costs	(3) Replacement Costs	(4) Salvage Value	(5) SPW	(6) PV O&M	(7) PV Replacement	(8) PV Salvage
Total					$0	$0	$0

Slide 7

E. TLCC Without Retrofit

(1) PV Energy	$1,651
(2) PV Investment	$ 0
(3) PV Annual O&M	$ 897
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$2,548

Slide 8



F. Energy Costs With Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Other Steam	42,408 lbs.	$0.0049/lb.	$207.80 Base	5.18	$1,076
			$ 15.34 Demand		$ 79
Total					$1,155

Slide 9

G. Investment Costs With Retrofit

(1) Actual Costs	$175.70
(2) Adjustment Factor	0.9
(3) Adjusted Costs	$158.00
(4) Renovation Costs	$ 0
(5) Adjusted PV	$158.00

Slide 10

H. Annual Nonfuel O&M Costs With Retrofit

(1) Amount	(2) UPW	(3) PV Costs
$153.19	4.10	$628.00

Slide 11

I. NONANNUAL O&M, REPLACEMENT, AND SALVAGE WITH RETROFIT

(1) Year	(2) O&M Costs	(3) Replacement Costs	(4) Salvage Value	(5) SPW	(6) PV O&M	(7) PV Replacement	(8) PV Salvage
Total					$0	$0	$0

Slide 12

J. TLCC With Retrofit

(1) PV Energy	$1,155
(2) PV Adjusted Investment	$ 158
(3) PV Annual O&M	$ 628
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$1,941

Slide 13

K. Net Savings of Project

(1) TLCC Without	$2,548
(2) TLCC With	$1,941
(3) Net Savings	$ 607

Slide 14

L. SIR

(1) Numerator	
(a) Δ Energy Cost	$496
(b) Δ Nonfuel O&M	-$269
(c) Numerator	$765
(2) Denominator	
(a) Δ Investment	$158
(b) Δ Replacement	$ 0
(c) Δ Salvage	$ 0
(d) Denominator	$158
(3) SIR	4.84

Slide 15

PROJECT SELECTION - LIMITED BUDGET

PROJECTS	SIR	RANKING NO BUDGET CONSTRAINT	FIRST COST ($)	NET SAVINGS ($)
Water-saving devices	4.84	(7)	176	607
R,S,T,U	5.0	(6)	2,000	8,000
V	7.5	(5)	1,600	10,400
W	8.0	(4)	10,000	70,000
X	12.5	(1)	2,000	23,000
Y	12.0	(2)	3,000	33,000
Z	9.0	(3)	1,000	8,000

OPTIONS WITHIN BUDGET:	Project W		All project except W
	First cost = $10,000 NS = $70,000	or	First cost = $9,776 NS = $83,007

Section 12

Slide Presentation: Project Design, Sizing, and Selection

The purposes of this session are to (1) define economic efficiency in the context of project design, sizing, and selection; (2) cite practical examples for the seminar participants on how these economic efficiency decisions are a part of their work; (3) show graphically the net benefits or net savings implications of investing too much or too little in building projects; and to (4) illustrate with a residential case example the application of economic techniques in choosing cost-effective designs, sizes and projects among alternative energy conservation investments.

Slide 1

ECONOMIC EFFICIENCY IN PROJECT DESIGN, SIZING, AND SELECTION

Economic Efficiency in Project Design, Sizing, and Selection

- Present Introduction.
- Explain that there is an economically efficient design, size, or selection when choosing among building alternatives.
- Explain further that the economic objective is to seek the alternative that maximizes net benefits or net savings.

Slide 2

Project Choice

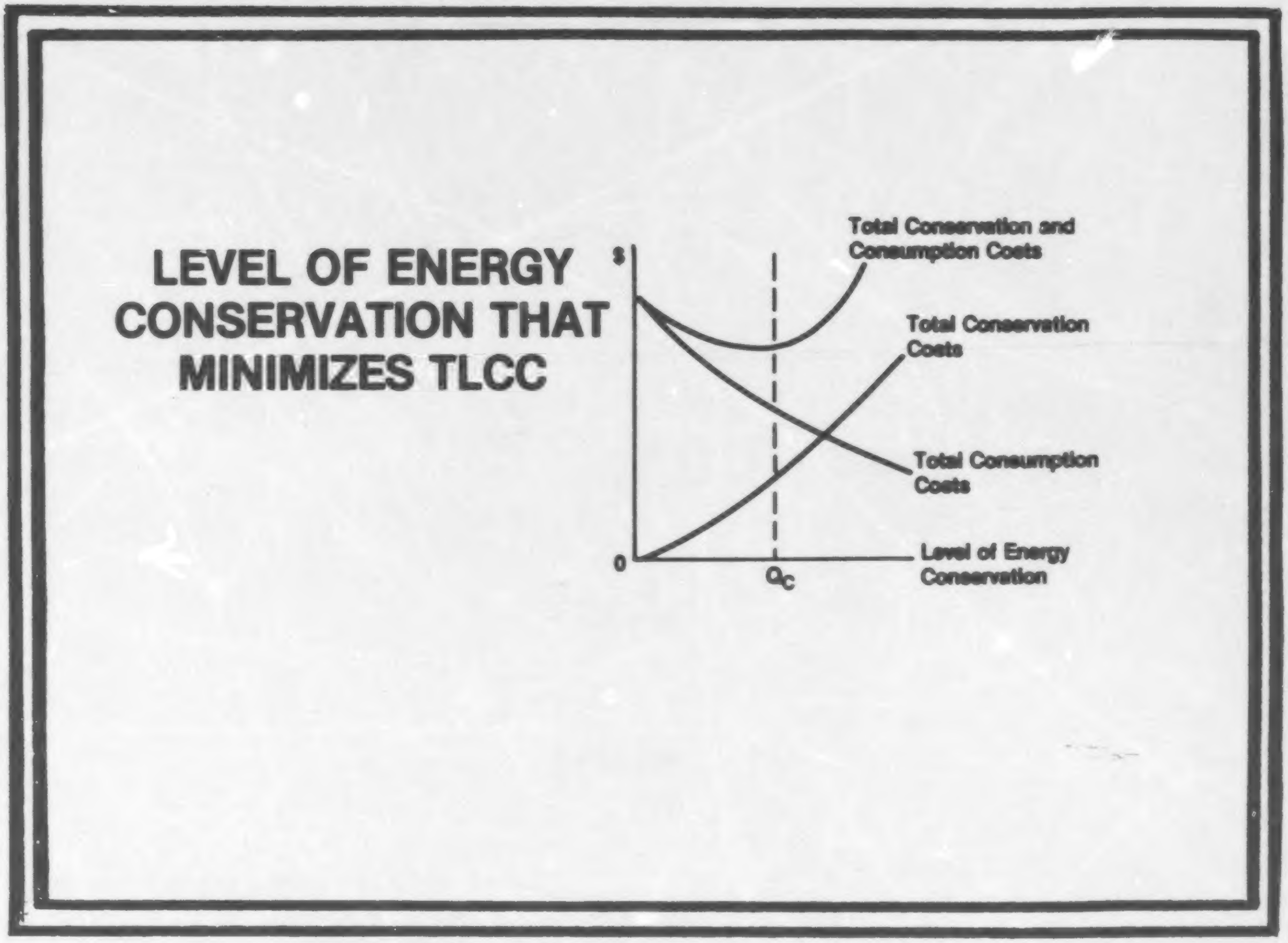
- Sizing
- Designing
- Ranking

Project Choice

Cite the following examples for the three types of choices:

- Choose thickness or R value of insulation -- Sizing.
- Choose one of alternative lighting systems, orientations of building, or of heating/cooling systems -- Designing.
- Choose among a group of retrofit projects including insulation, double glazing, and controls -- Ranking.

Slide 3

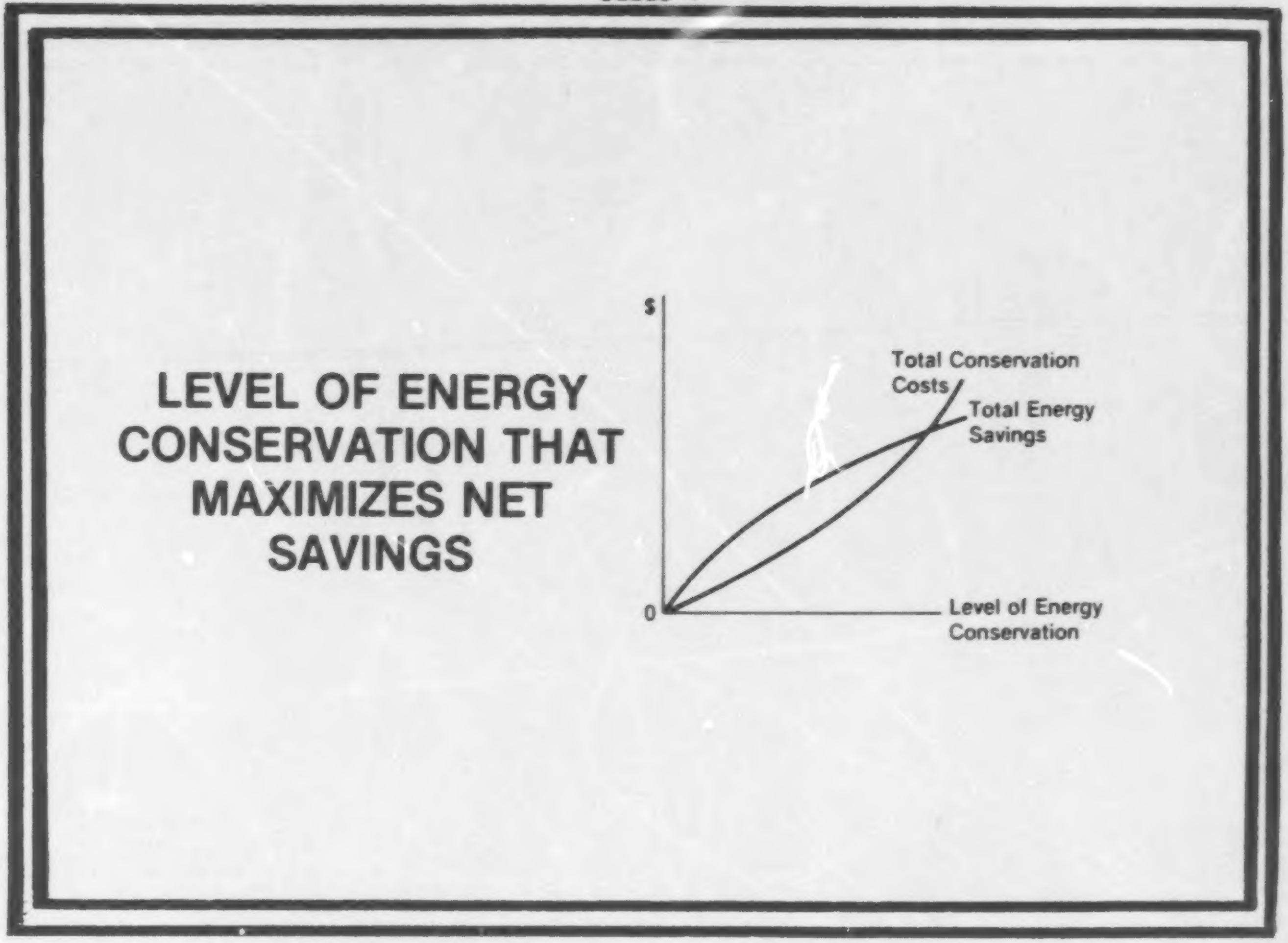


LEVEL OF ENERGY CONSERVATION THAT MINIMIZES TLCC

Level of Energy Conservation that Minimizes TLCC

- Explain the axes and curves.
- Point out the economically efficient level of conservation (scale or size) at which TLCC are minimized.
- Describe the cost implications if more or less is invested in conservation than the economically efficient level.

Slide 4

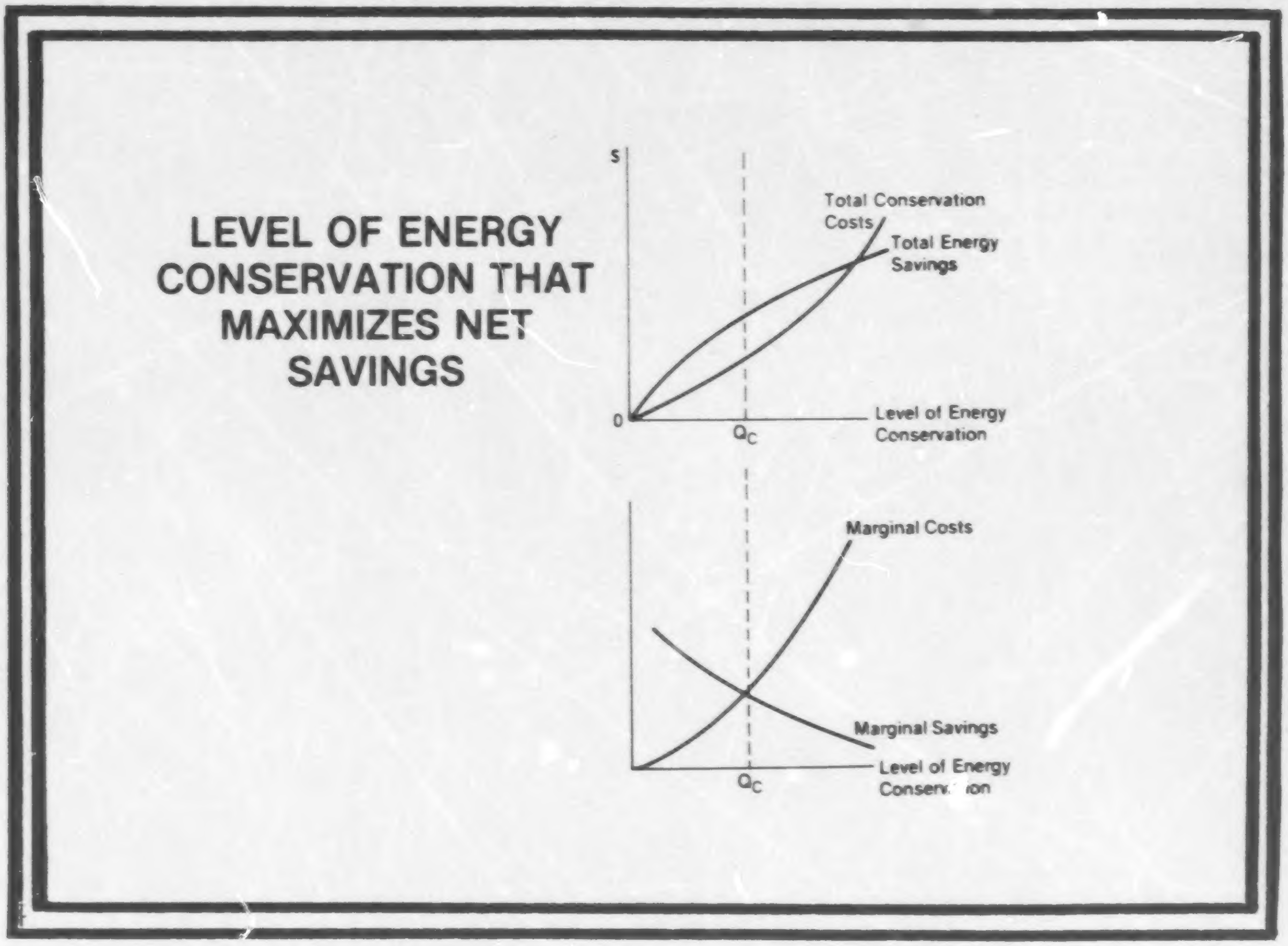


LEVEL OF ENERGY CONSERVATION THAT MAXIMIZES NET SAVINGS

Level of Energy Conservation that Maximizes Net Savings--I

- o Explain the axes and curves.
- o Explain how this graph provides an alternative display of efficient scale or design.
- o Explain that conservation is "generally" cost effective as long as there are positive NS, but there is only one level where conservation is at its most efficient level.
- o Indicate the level of conservation at which NS are maximized, and explain why NS diminish at lower and higher levels.

Slide 5



LEVEL OF ENERGY CONSERVATION THAT MAXIMIZES NET SAVINGS

Level of Energy Conservation that Maximizes Net Savings--II

- Explain the axes and curves of new graph.
- Explain how the economically efficient level of conservation will be the same for the two graphs.
- Note what happens when you invest more or less than the economically efficient level.

BEST COPY AVAILABLE

Slide 6

CASE EXAMPLES, RESIDENTIAL ENERGY CONSERVATION

Case Examples, Residential Energy Conservation

- Explain that the sizing, designing, and ranking choices are made for all types of buildings and building components.
- Note that a residential building was selected because it is simpler to explain and understand than a commercial building.
- Explain that the purpose of the case example is to illustrate how economically efficient project designs and sizes can be determined, and how economically efficient selections are made among alternative energy conservation projects with and without budget constraints.

Slide 7

Outline

I. Evaluating Cost Effectiveness of Insulation

II. Sizing Insulation

III. Selecting Among Envelope Modifications

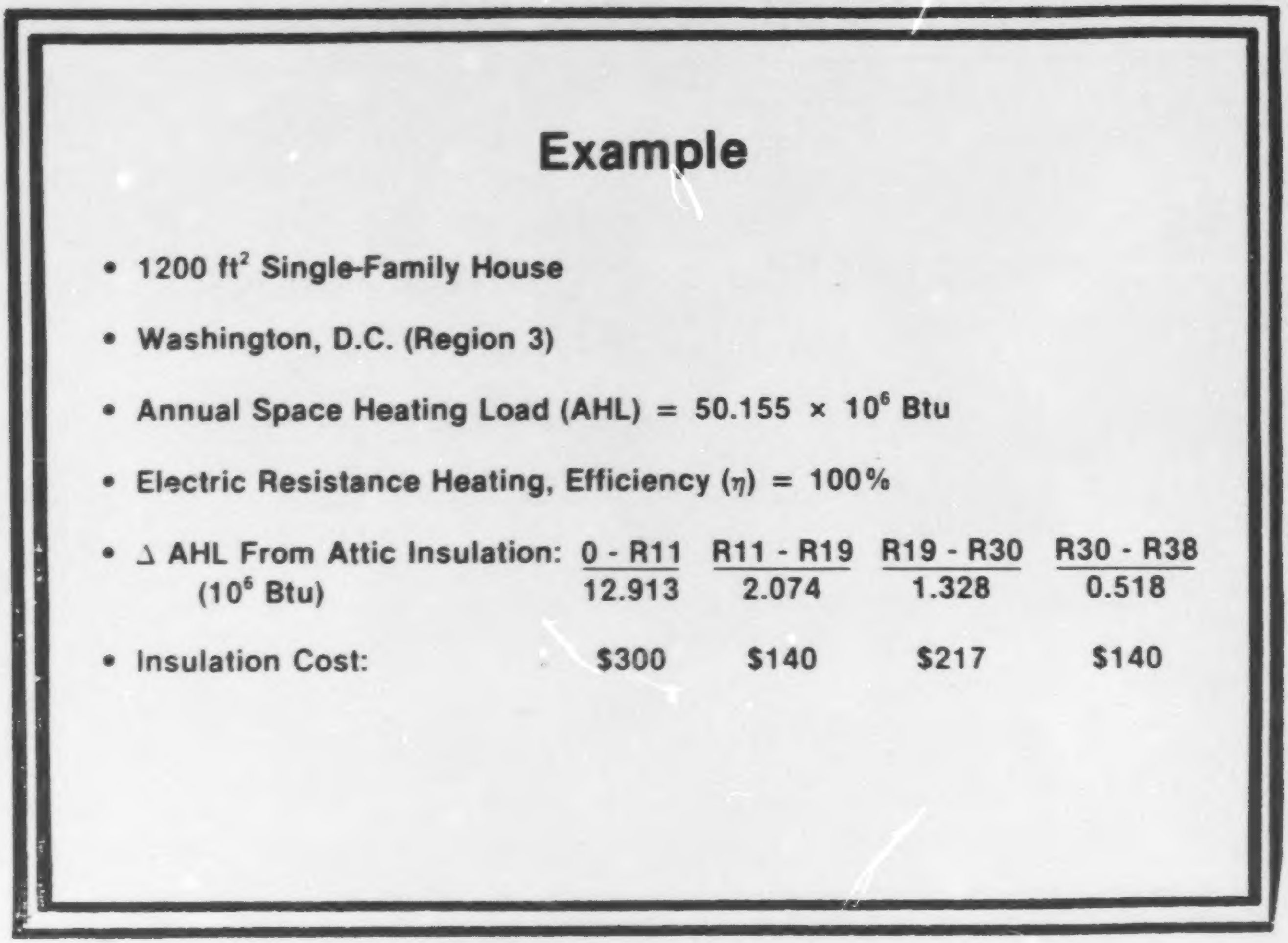
IV. Equipment Selection

V. Interdependence

Outline

- Describe topics of the session according to the outline.

Slide 8



Example

- 1200 ft^2 Single-Family House
- Washington, D.C. (Region 3)
- Annual Space Heating Load (AHL) = 50.155×10^6 Btu
- Electric Resistance Heating, Efficiency (η) = 100%

	0 - R11	R11 - R19	R19 - R30	R30 - R38
• Δ AHL From Attic Insulation: (10^6 Btu)	12.913	2.074	1.328	0.518
• Insulation Cost:	\$300	\$140	\$217	\$140

Example

- o Explain each of the data lines in the table.
- o Note that the entries for ΔAHL represent decreasing marginal reductions in AHL for each of the increments in insulation.[1]
- o Note also that the costs are marginal costs for those same increments in insulation.
- o Explain that the study period is 25 years and the discount rate is 7%.

---

[1] The reductions in annual heating load from increased insulation are taken from Stephen R. Petersen, Economics and Energy Conservation in the Design of New Single-Family Housing, NBSIR 81-2380, National Bureau of Standards, Washington, DC, 1981, pp. 62-63.

Slide 9

Annual Heating Energy Requirement (AHR)

$$AHR = \frac{AHL}{\eta} = \frac{50.155 \times 10^6 \text{ Btu}}{1}$$

Annual Heating Energy Requirements (AHR)

- o Explain that the AHL is a function of degree days (i.e., the climate) and the resistance of the building envelope.
- o Explain the equation.

Slide 10

Cost Effectiveness of 0 - R11 Attic Insulation

$$ES = \frac{\Delta AHL}{\eta} \cdot P \cdot UPW^*$$

$$= 12.913 \times 10^6 \text{ Btu} \cdot \$16.77/10^6 \text{ Btu} \cdot 14.34 = \$3{,}105$$

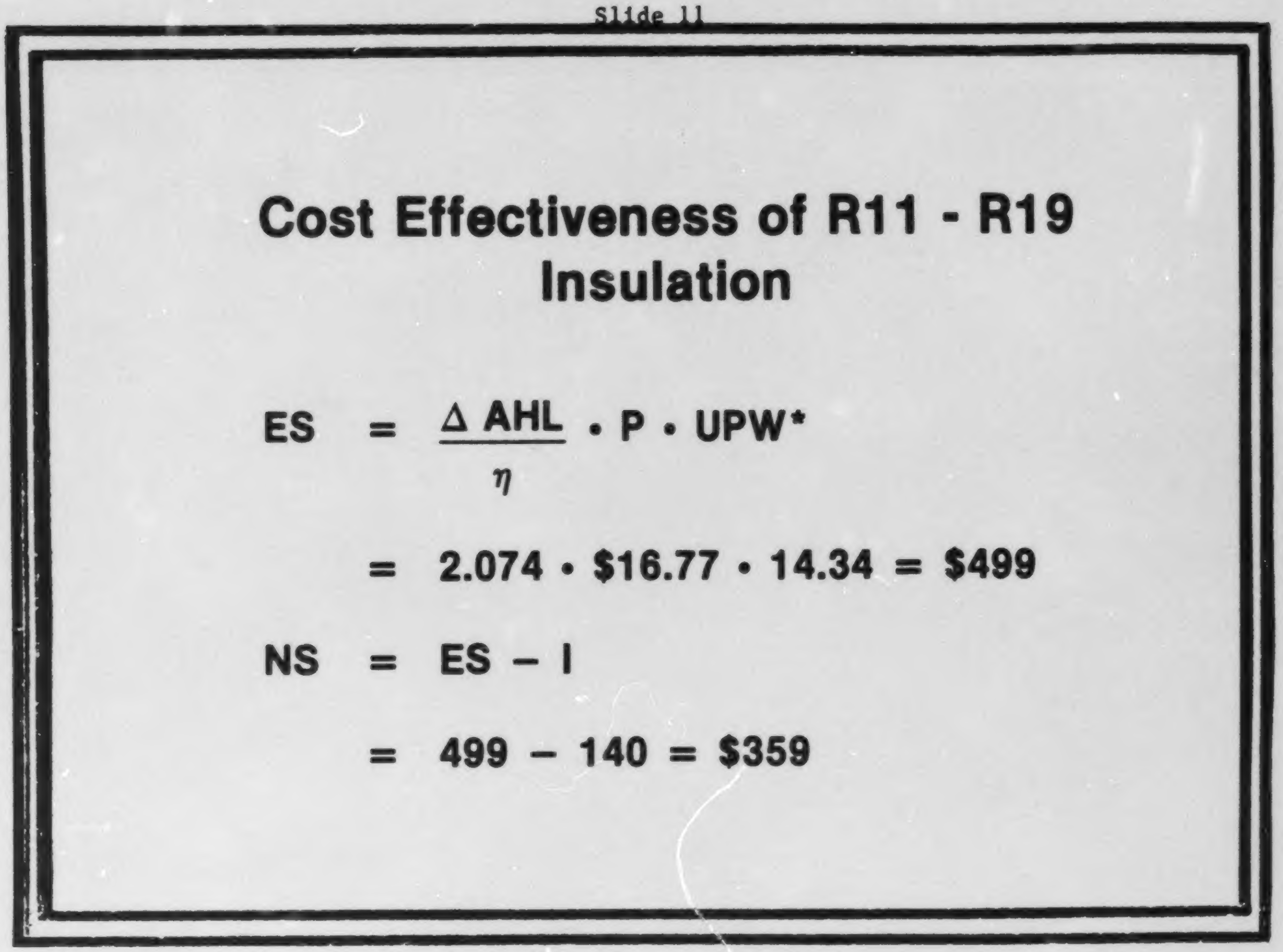
$$NS = ES - I$$

$$= \$3{,}105 - \$300 = \$2{,}805$$

Cost Effectiveness of 0-R 11 Attic Insulation

- Describe the source of the data and the calculation procedures.
- Explain how to calculate the NS for 0-R 11 insulation.
- Explain why the UPW* tables are used for the discount factor.

Slide 11



Cost Effectiveness of R11 - R19 Insulation

$$ES = \frac{\Delta AHL}{\eta} \cdot P \cdot UPW^*$$

$$= 2.074 \cdot \$16.77 \cdot 14.34 = \$499$$

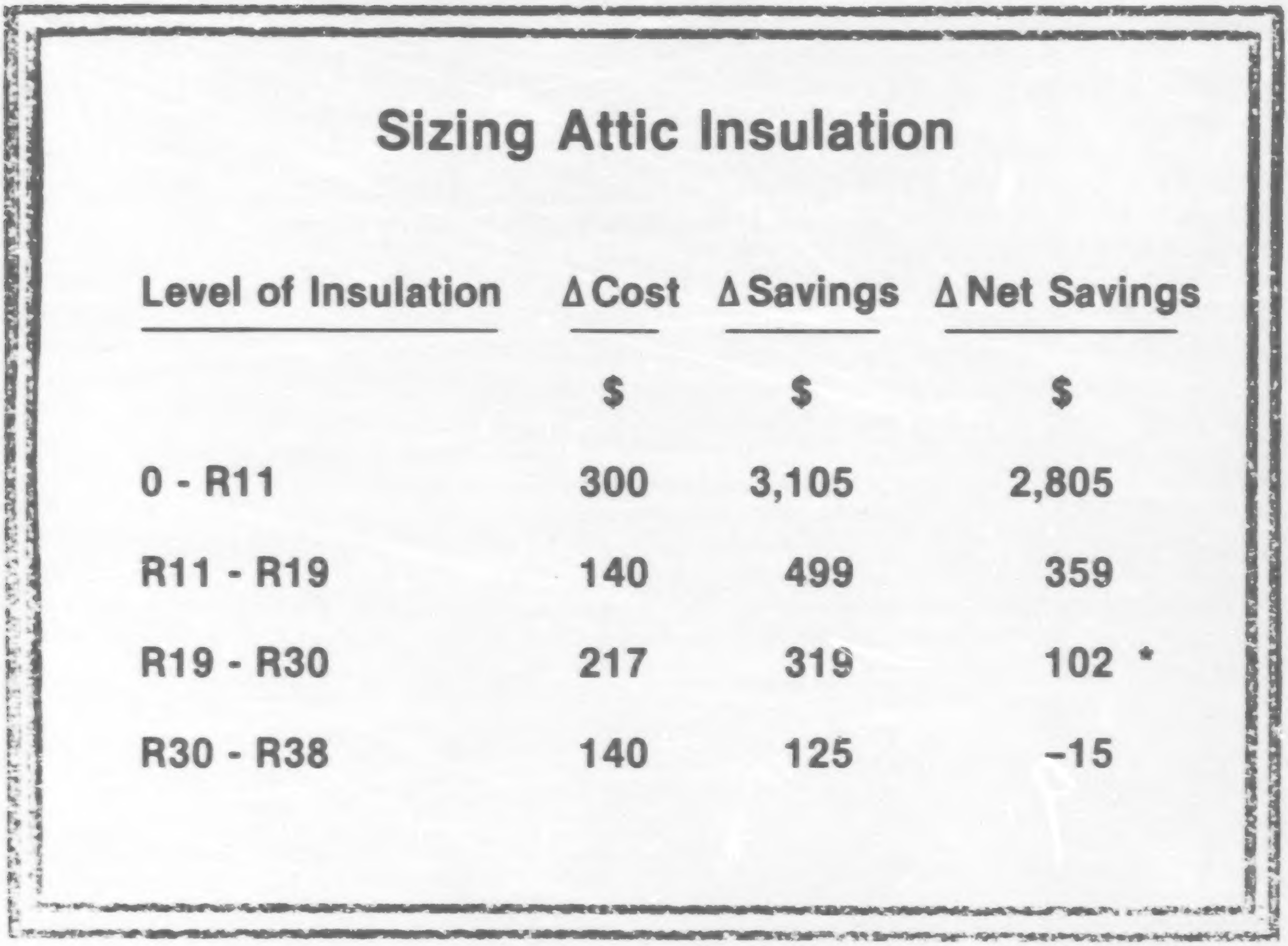
$$NS = ES - I$$

$$= 499 - 140 = \$359$$

Cost Effectiveness of R 11 - R 19 Insulation

- Describe the source of the data and the calculation procedures.

Slide 12



Sizing Attic Insulation

Level of Insulation	Δ Cost	Δ Savings	Δ Net Savings
	$	$	$
0 - R11	300	3,105	2,805
R11 - R19	140	499	359
R19 - R30	217	319	102 *
R30 - R38	140	125	−15

Sizing Attic Insulation

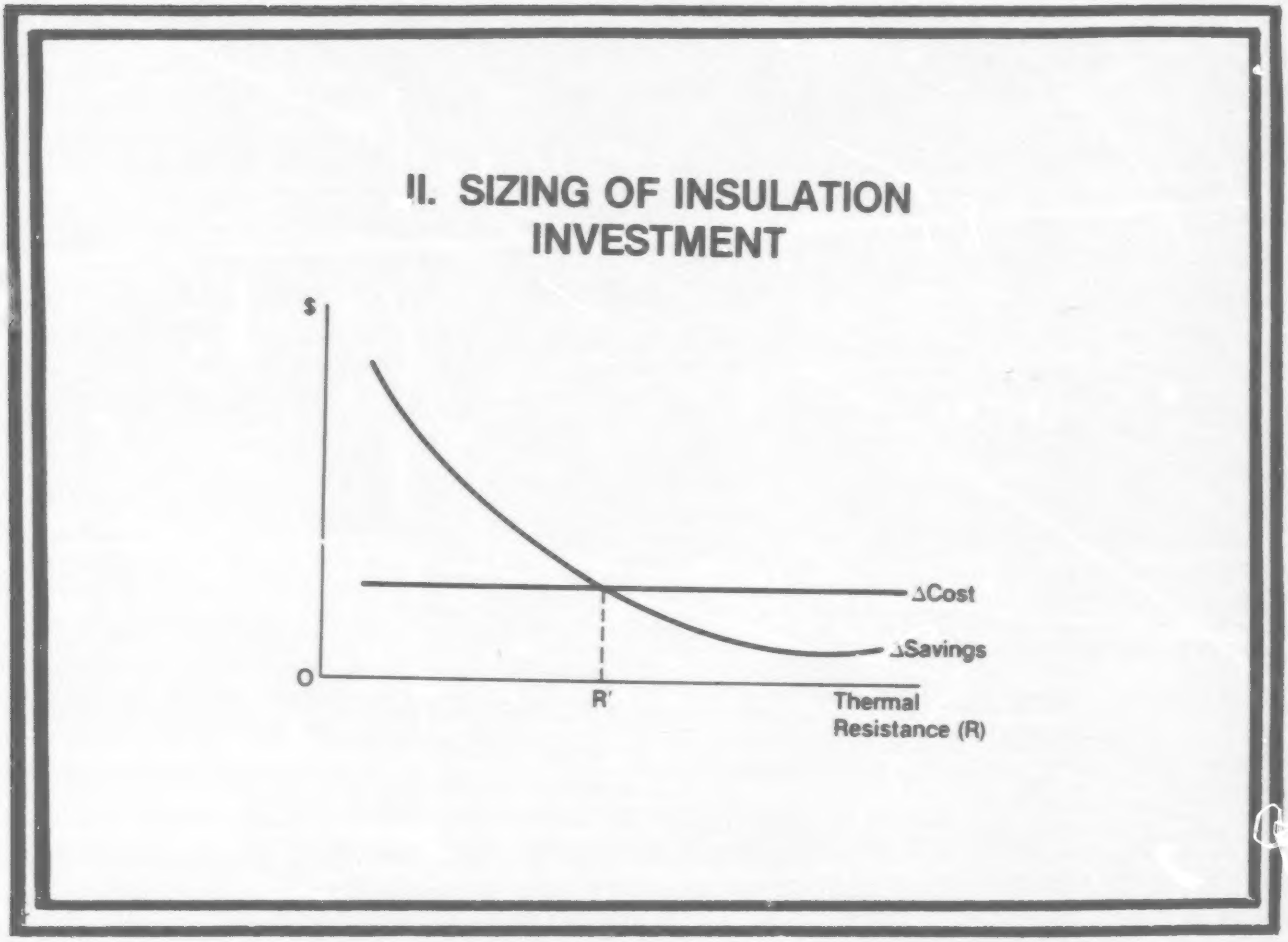
- Explain that the table shows the results of NS (NB) analysis.
- Describe the data. Note that the last column lists the incremental net savings for the last increment of insulation.
- Explain why R 30 is most efficient.
- Explain why higher or lower levels of insulation are inefficient by showing the total net savings of the following three insulation levels:

  R 19 Total Net Savings = $3,164.

  R 30 Total Net Savings = $3,266.

  R 38 Total Net Savings = $3,251.

Slide 13

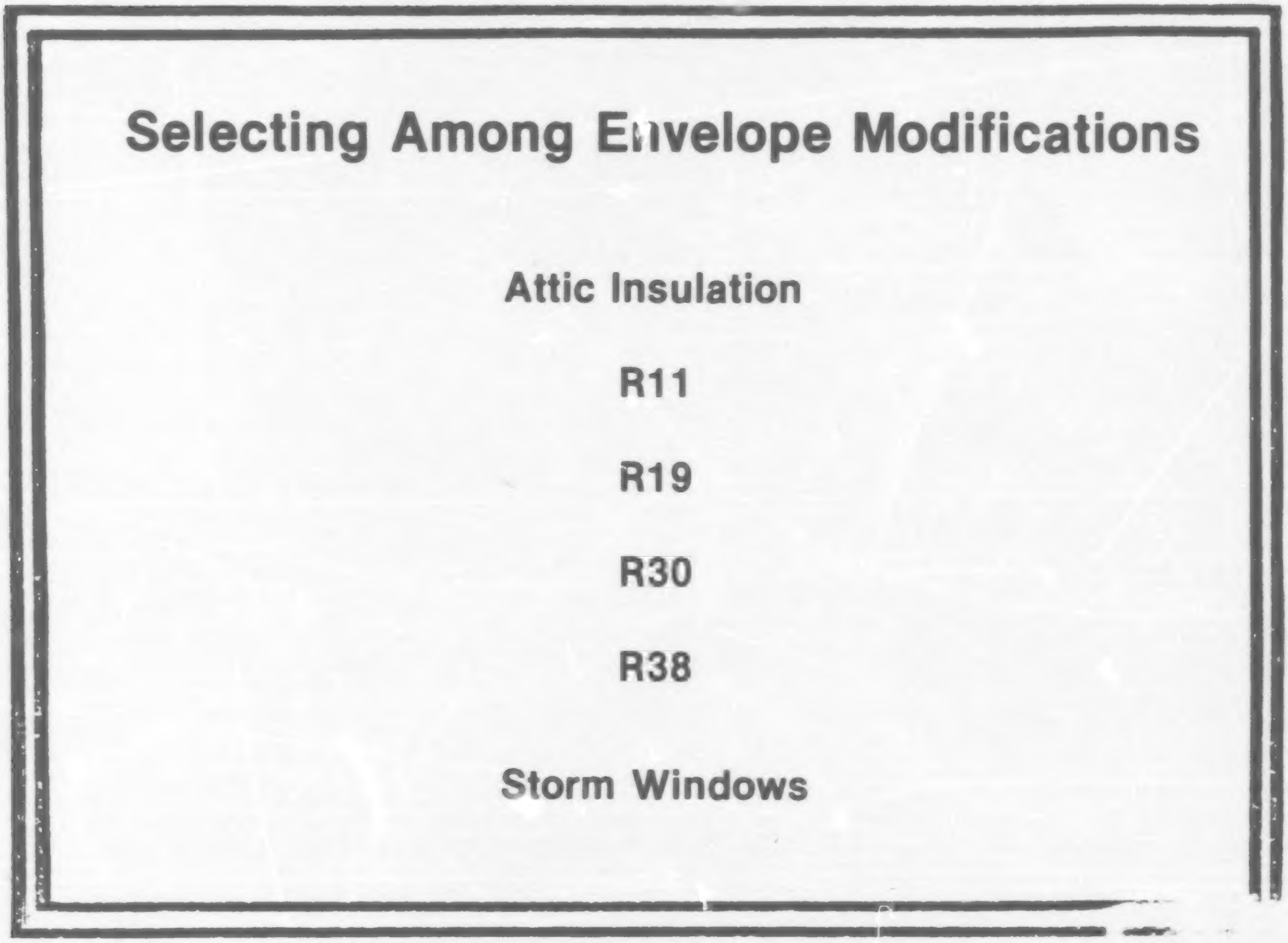


II. SIZING OF INSULATION INVESTMENT

Sizing of Insulation Investment

- Explain the axes and curves.
- Describe how the graph confirms the conclusions of the previous slide that there can be too much or too little insulation on economic grounds.

Slide 14



Selecting Among Envelope Modifications

Attic Insulation

R11

R19

R30

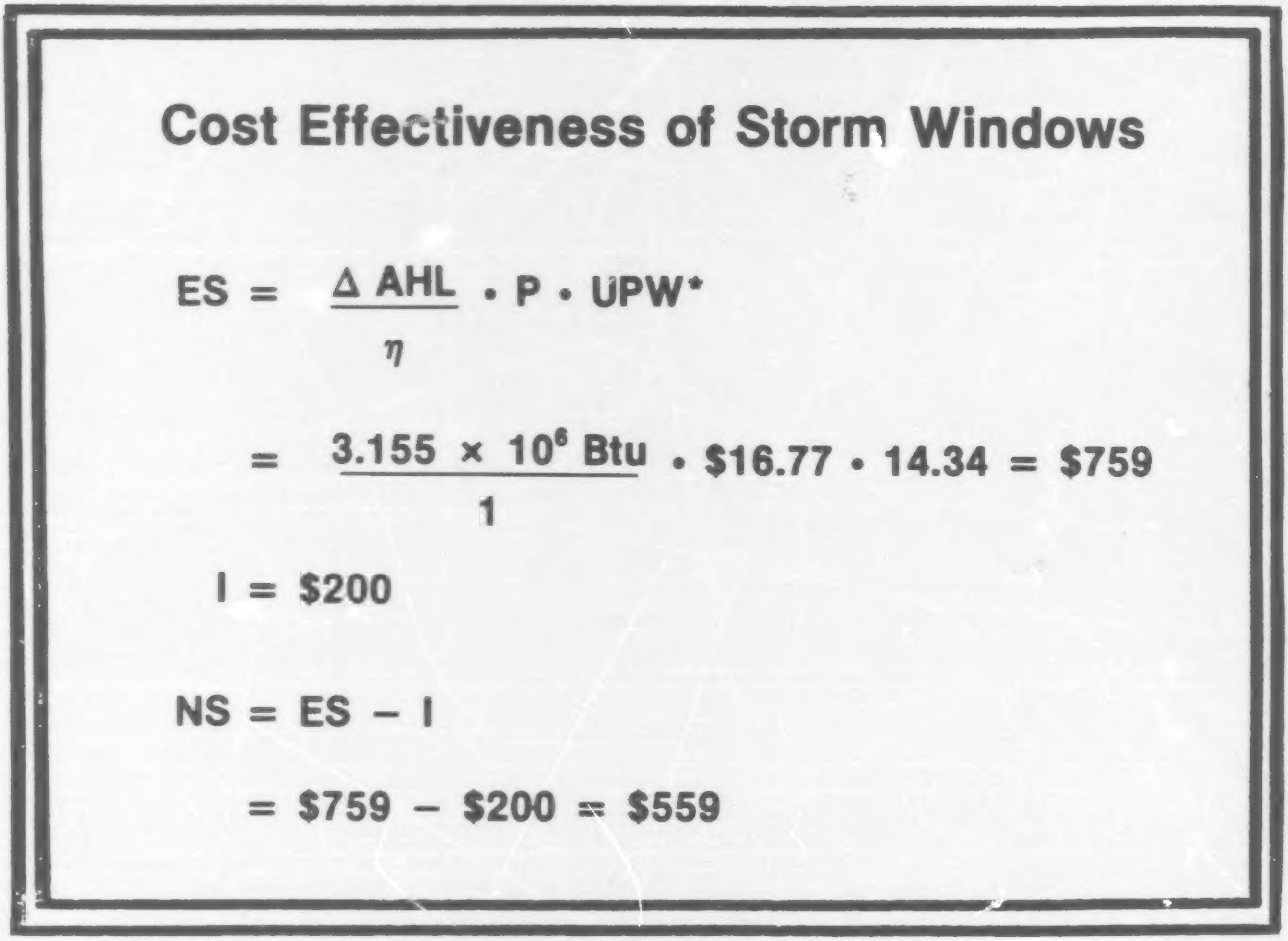
R38

Storm Windows

Selecting Among Envelope Modifications

- Introduce another envelope modification, storm windows, into the evaluation.
- Explain why economic analysis is needed to choose among different levels of insulation and storm windows when there is not enough money to do all that are cost effective.

Slide 15



Cost Effectiveness of Storm Windows

$$ES = \frac{\Delta AHL}{\eta} \cdot P \cdot UPW^{*}$$

$$= \frac{3.155 \times 10^{6}\ \text{Btu}}{1} \cdot \$16.77 \cdot 14.34 = \$759$$

$$I = \$200$$

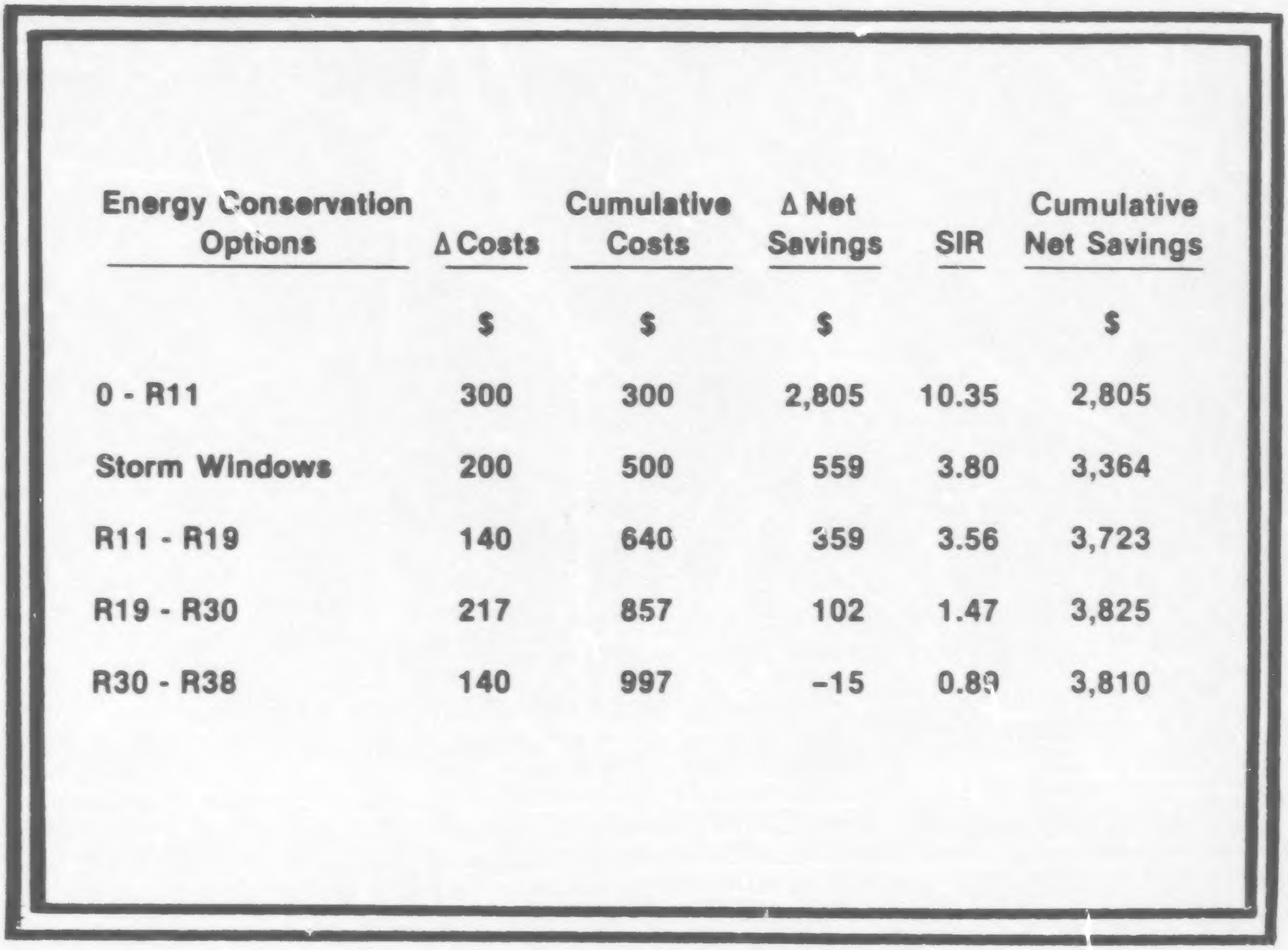
$$NS = ES - I$$

$$= \$759 - \$200 = \$559$$

Cost Effectiveness of Storm Windows

- Describe the source of the data and the procedures for calculating ES.
- Describe how NS are calculated.
- Explain that, in the absence of a budget constraint, R 30 insulation and the storm windows would be selected. But with a budget constraint, SIR values are needed to make a final selection.
- Ask the class to compute the SIR for storm windows. It would be calculated as follows: ES ÷ I = \$759 ÷ 200 = 3.8.

Slide 16



Energy Conservation Options	Δ Costs	Cumulative Costs	Δ Net Savings	SIR	Cumulative Net Savings
	$	$	$		$
0 - R11	300	300	2,805	10.35	2,805
Storm Windows	200	500	559	3.80	3,364
R11 - R19	140	640	359	3.56	3,723
R19 - R30	217	857	102	1.47	3,825
R30 - R38	140	997	−15	0.89	3,810

SIR Table

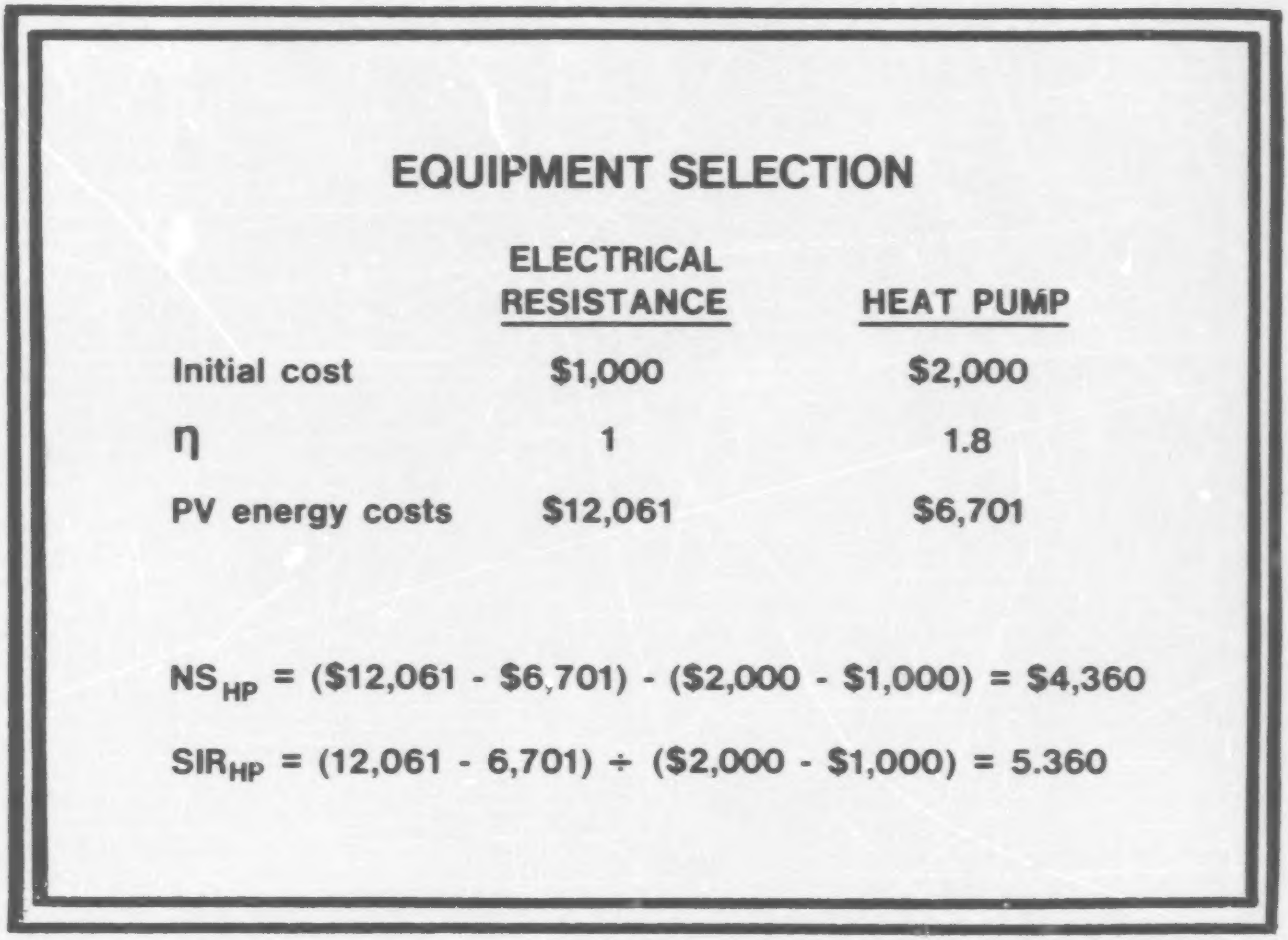
- Explain that the options are listed in order of their SIR values; i.e., total savings ÷ investment.
- Describe how cumulative net savings increase as long as the SIR > 1.0. Thus all options up to R 30 are efficient with no budget limitation.
- Ask the class what would be the cost effective selection with a $500 budget. Explain why only R 11 and storm windows would be chosen with that budget.
- Comment on how the sizing and ranking decisions have been carried out simultaneously in this problem.
- Note that the figures for calculating the SIR are not apparent in the table, but they can be derived. For example, for R 11, the SIR = energy savings ÷ cost = (2805 + 300) ÷ 300 = 10.35.

INTERDEPENDENCE
BETWEEN
EQUIPMENT AND ENVELOPE
RETROFIT PROJECTS

Interdependence Between Envelope and Equipment Retrofit Projects

- Explain that energy savings from envelope modifications are interdependent with equipment modifications.
- Explain, for example, that dollar energy savings estimates will therefore vary for insulation, depending on the efficiency of the heating equipment in that building.

Slide 18



EQUIPMENT SELECTION

	ELECTRICAL RESISTANCE	HEAT PUMP
Initial cost	\$1,000	\$2,000
η	1	1.8
PV energy costs	\$12,061	\$6,701

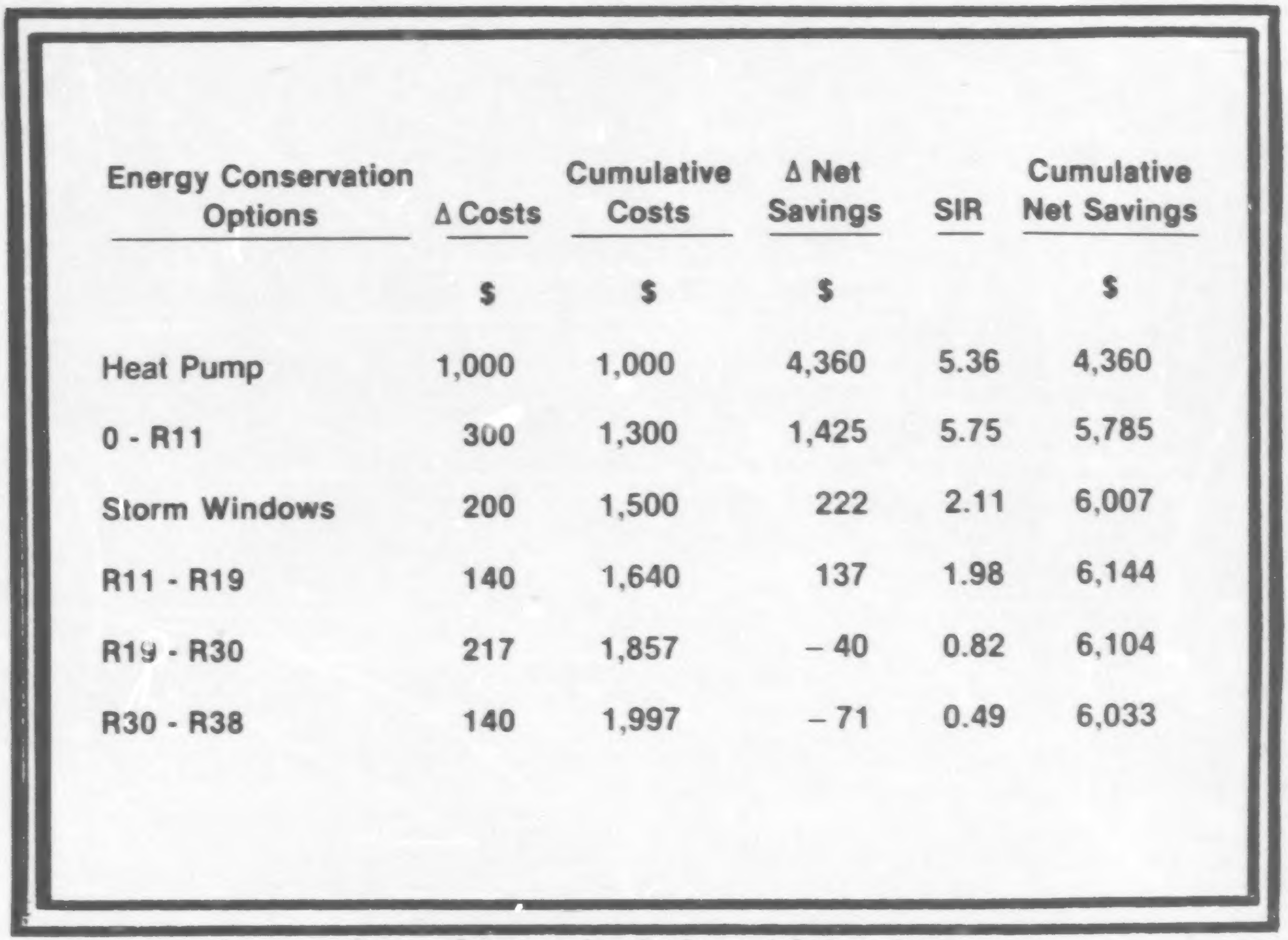
NS_{HP} = (\$12,061 - \$6,701) - (\$2,000 - \$1,000) = \$4,360

SIR_{HP} = (12,061 - 6,701) ÷ (\$2,000 - \$1,000) = 5.360

Equipment Selection

- Explain that adding equipment changes to the options list of storm windows and insulation requires computing an SIR value for comparison.
- Explain the data.
- Describe how NS_{HP} and SIR_{HP} are determined.

Slide 19



Energy Conservation Options	Δ Costs	Cumulative Costs	Δ Net Savings	SIR	Cumulative Net Savings
	$	$	$		$
Heat Pump	1,000	1,000	4,360	5.36	4,360
0 - R11	300	1,300	1,425	5.75	5,785
Storm Windows	200	1,500	222	2.11	6,007
R11 - R19	140	1,640	137	1.98	6,144
R19 - R30	217	1,857	– 40	0.82	6,104
R30 - R38	140	1,997	– 71	0.49	6,033

Energy Conservation Options with Heat Pump

- Explain that the insulation and storm window options now have new SIR's due to different equipment assumptions.

- Explain that the heat pump is listed first even though its SIR is less than the SIR of R 11 insulation because the heat pump ranks high enough that it will be included. Since all of the other SIR's are a function of the equipment, it is specified first so that the appropriate SIR's can be calculated.

- Indicate that R 19 instead of R 30 is now the cost effective level.

- Note that the value of energy savings for any envelope modification with a heat pump is less than the savings with the electric resistance system, since the heat pump can meet any given AHL with less energy than the electric system.

- Note further that the interdependence works both ways, so that in a commercial building, for example, the equipment might be sized in response to the envelope modifications.

Section 13

Presentation: Treatment of Inflation

The main purpose of this session is to contrast analyses made in constant dollars with analyses made in current dollars. Secondary purposes are to review the procedure for escalating costs and to distinguish budgetary needs for estimates of future costs from the requirements of an economic evaluation.

This session can be presented on the blackboard or flip chart; no slides are provided. The presentation is based on the material presented in Section 3 of the Seminar Workbook and the series of questions and answers provided here.

Because this is a topic with which participants often have difficulty, a recommended approach is, first, to assign the reading of Section 3 of the Workbook for homework the first night. Second, in the lecture the following day, it is helpful to review the homework material, including blackboard presentation of the graphs in section 3 of the workbook. Third, the series of four questions and answers found below can complete the lecture. First list the assumptions on the board, then ask each question, discuss it, and give its solution on the board.

The series of questions and answers presented below for a case example help to explain the difference between constant dollar and current dollar analyses. Given the following data and assumptions:

- A particular building component is being considered for purchase and installation 5 years from now;
- the building component could be purchased and installed today for a cost, C_0, of $1,000;

- the price of the building component is projected to escalate 5 percent faster than the rate of general price inflation over the next 5 years, i.e., $e = .05$;

- the rate of general price inflation, I, is projected at 5 percent per year over the next 5 years, i.e., $I = .05$; and

- the project is a Federal project that does not involve energy conservation; hence, project evaluation is subject to a 10 percent real discount rate; i.e., $d = .10$;

Answer the following questions:

Question #1:

What is the estimated constant dollar cost, C_e, of the building component in 5 years?

Solution:

$$C_e = C_0 \times (1 + e)^N$$

$$= \$1,000 \times (1 + .05)^5$$

$$= \$1,276.$$

Question #2:

What is the present value equivalent, P_{C5}, of the cost of purchasing and installing the component 5 years hence?

Solution:

$$P_{C_e} = C_e \times \frac{1}{(1 + d)^N}$$

$$= \$1,275 \times \frac{1}{(1 + .10)^5}$$

$$= \$792.$$

[Note: The preceding escalation and discounting operations shown in solutions to #1 and #2, are usually combined as follows:

$$P_{C_e} = C_0 \left(\frac{1 + e}{1 + d}\right)^5 = \$1,000 \left(\frac{1 + .05}{1 + .10}\right)^5 = \$792.]$$

Question #3:

What amount, C_E, would be included in the 5-year budget projection for actually purchasing and installing the component?

Solution:

$$C_E = C_0 \text{ X } (1 + E)^N$$

$$= \$1{,}000 \text{ X } (1 + .1025)^5$$

$$= \$1{,}629.$$

$$E = e + I + eI$$

$$= .05 + .05 + (.05)(.05)$$

$$= .1025.$$

Question #4:

What is the present value equivalent, P_{C_E}, of the budgeted amount?

Solution:

$$P_{C_E} = C_E \text{ X } \frac{1}{(1 + D)^N}$$

$$= \$1{,}629 \text{ X } \frac{1}{(1 + .155)^5}$$

$$= \$792.$$

$$D = d + I + dI$$

$$= .10 + .05 + (.10)(.05)$$

$$= .155.$$

[Note: The preceding escalation and discounting operations, shown in solutions to #3 and #4, are usually combined as follows:

$$P_{C_E} = C_0 \left(\frac{1 + E}{1 + D}\right)^5 = \$1{,}000 \left(\frac{1 + .1025}{1 + .155}\right)^5 = \$792.$$

Also note that the present value equivalent of the current dollar budget amount (#4) is equal to the present value equivalent of the constant dollar amount (#2).]

Section 14

Team Problem: Planning an Energy Conservation Package For Maximum Net Savings (80 Minutes)

This problem requires class teams to determine the cost effectiveness of each of four envelope and equipment investments and then to decide what combination of those investments is most economical for a given budget. The problem includes accounting for interdependencies between envelope and equipment modifications.

The purposes of the problem are as follows:

(1) to develop team skills in performing economic evaluations;

(2) to gain additional practice in calculating the net savings and the SIR for conservation investments;

(3) to give insight into evaluating interdependent alternatives; and

(4) to practice choosing among alternatives with a limited budget.

Allow the class about five minutes to read the problem. Explain the purposes of doing the problem (see above) and what type of answers are called for. Ask for questions. Break the class into five or six teams of three to six persons each. Avoid having persons who work together on the same team. Have the first team to finish calculations for Option A raise their hand and go through their schedules. Do the same for the remaining three options.

Note that Option C, adding insulation to a level of R-19, requires two sets of entries in the schedules--one for adding insulation without the heat pump, and one for adding insulation with the heat pump. The interdependence effect between the heat pump and the insulation is illustrated by the differential net savings shown in slide 24.

Note also that if the building were very large, the heat pump might have been sized differently for different levels of insulation, thereby taking into account the impact of insulation (envelope modifications) on equipment.

Given the data on each of the four options, have the teams use their Project Selection worksheet (found in the Workbook) to establish economic priority among the options and select the economically efficient combination for a $2,000 budget. Explain why insulation without the heat pump is ignored.

Conclude by giving a short summary of how the problem was solved and by answering any questions.

Team Problem--Planning an Energy Conservation Package

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Statement: Plan an energy conservation package for military base housing that will maximize net savings, given the following conditions and candidate retrofit projects. The housing is located in Washington, D.C. Its remaining life is expected to be 15 years. The agency has a limited budget of $2,000 to spend on each house.

Each house has been weatherstripped and caulked. It has R-11 insulation in the attic, as well as all the insulation that can be accommodated in the floors and walls without making major structural modifications. A jacket has been added to the domestic water heater, and thermal draperies have been added to the windows.

Each house is currently heated by an electric resistance system that is in good condition and could reasonably be expected to last over the remaining 15 year life of the house with only negligible maintenance and repair. The efficiency of the system is assumed to be 100 percent. The annual space heating load is 100 x 10^6Btu per house. The base now pays $16.89 per 10^6Btu ($0.06 per kWh) of electricity. The annual domestic hot water load is 22 x 10^6Btu per house. Hot water is currently supplied by an electric water heater that is expected to last over the remaining 15 year life of the house with only negligible maintenance and repair. The efficiency of the existing hot water system is assumed to be 100 percent.

The following options are being considered for retrofit to each house:

(A) Addition of a solar domestic water heater. The system that has been recommended as reliable and sufficiently durable to last the 15 years without major maintenance or repair costs $1,600, and is expected to meet 80 percent of the annual hot water load. No net salvage value is expected.

(B) Replacement of the existing electric resistance space heating system with a higher efficiency (1.8 COP) heat pump. The replacement of the existing system with the heat pump will cost $1,700. No net salvage value is expected from disposal of the existing system. The heat pump is expected to have about the same maintenance and repair costs and life expectancy as the existing system.

(C) Addition of attic insulation to raise the current resistance (R) level from R-11 to R-19. The insulation will cost $300 to purchase and install and is expected to reduce the energy consumption for space heating by 5 percent.

(D) Replacement of incandescent lighting with fluorescent lighting. The fluorescent lighting will cost $300 to purchase and install and is expected to reduce by 60 percent the 2000 kWh annual consumption rate of the existing lighting. Over the 15 year project life, the economic effects of the longer lives of the fluorescent tubes and their higher replacement costs are expected to be offsetting. There are assumed to be no salvage values associated with either the incandescent or fluorescent lighting.

Planning an Energy Conservation Package for Maximum Net Savings

Remarks to Help the Class

Slide

3 The UPW* factor of 11.07 is found in Handbook 135 on page 120, Table B-3, under N=15, for residential buildings using electricity.

5 Since the solar system is expected to generate 80% of the hot water load, the annual consumption with the solar system will be 4.4×10^6 Btu (i.e., $.20 \times 22 \times 10^6$ Btu).

13 The higher efficiency (1.8 COP) heat pump reduces the 100×10^6 Btu heating requirements with the electric system as follows:

$$AHR = AHL/\eta = \frac{100}{1.8} = 55.56.$$

193

Slide 1

PLANNING AN ENERGY CONSERVATION PACKAGE FOR MAXIMUM NET SAVINGS

Identifying Information

Building:

Location Washington, DC

DOE Region 3

Use Military Base Housing

Type Residential

Life 15 Years

Project Install Solar Domestic Water Heater

Project Life 15 Years

Study Period 15 Years

Slide 3

A. Energy Costs Without Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	22 MBtu	$16.89/MBtu	$371.58	11.07	$4113
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$4113

Slide 4

E. TLCC Without Retrofit

(1) PV Energy	$4113
(2) PV Investment	$ 0
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$4113

Slide 5

F. Energy Costs With Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	4.4 MBtu	$16.89/MBtu	$74.32	11.07	$823
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$823

Slide 6

G. Investment Costs With Retrofit

(1) Actual Costs	$1600
(2) Adjustment Factor	0.9
(3) Adjusted Costs	$1440
(4) Renovation Costs	$ 0
(5) Adjusted PV	$1440

Slide 7

J. TLCC With Retrofit

(1) PV Energy	$ 823
(2) PV Adjusted Investment	$1440
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$2263

Slide 8

K. Net Savings of Project

(1) TLCC Without	$4113
(2) TLCC With	$2263
(3) Net Savings	$1850

L. SIR

(1)	Numerator	
	(a) Δ Energy Cost	$3290
	(b) Δ Nonfuel O&M	$ 0
	(c) Numerator	$3290
(2)	Denominator	
	(a) Δ Investment	$1440
	(b) Δ Replacement	$ 0
	(c) Δ Salvage	$ 0
	(d) Denominator	$1440
(3)	SIR	2.28

Slide 10

Identifying Information

Building:	
Location	**Washington, DC**
DOE Region	**3**
Use	**Military Base Housing**
Type	**Residential**
Life	**15 Years**
Project	**Install Heat Pump**
Project Life	**15 Years**
Study Period	**15 Years**

Slide 11

A. Energy Costs Without Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	100 MBtu	$16.89/MBtu	$1,689.00	11.07	$18,697
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$18,697

Slide 12

E. TLCC Without Retrofit

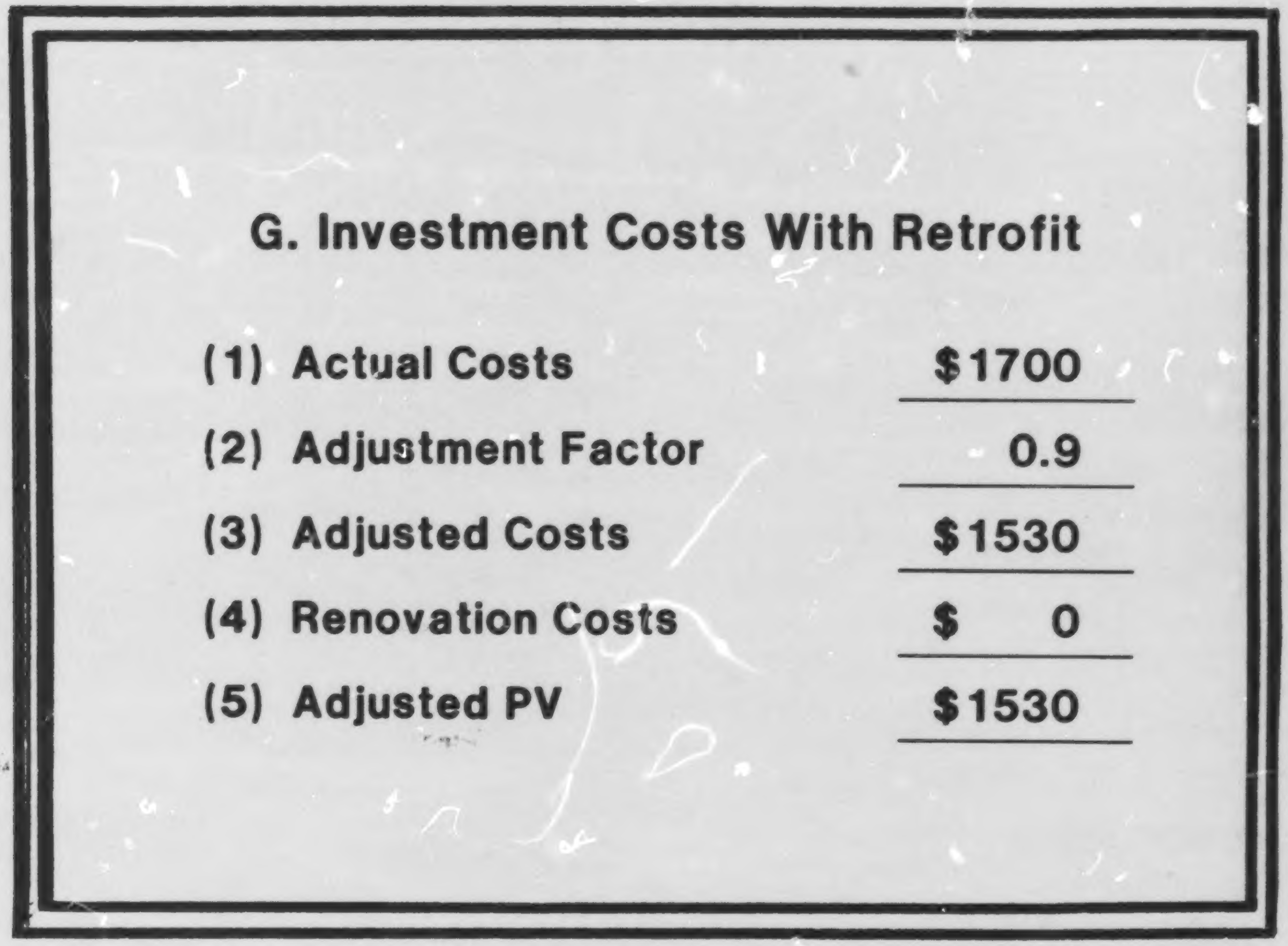
(1)	PV Energy	$18,697
(2)	PV Investment	$ 0
(3)	PV Annual O&M	$ 0
(4)	PV Nonannual O&M	$ 0
(5)	PV Replacement	$ 0
(6)	PV Salvage	$ 0
(7)	TLCC	$18,697

Slide 13

F. Energy Costs With Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	55.56 MBtu	$16.89/MBtu	$938.41	11.07	$10,388
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$10,388

Slide 14



G. Investment Costs With Retrofit

(1) Actual Costs	$1700
(2) Adjustment Factor	0.9
(3) Adjusted Costs	$1530
(4) Renovation Costs	$ 0
(5) Adjusted PV	$1530

Slide 15

J. TLCC With Retrofit

(1) PV Energy	$10,388
(2) PV Adjusted Investment	$ 1530
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$11,918

Slide 16

K. Net Savings of Project

(1) TLCC Without	$18,697
(2) TLCC With	$11,918
(3) Net Savings	$ 6779

Slide 17

L. SIR

(1)	Numerator	
	(a) Δ Energy Cost	$ 8309
	(b) Δ Nonfuel O&M	$ 0
	(c) Numerator	$ 8309
(2)	Denominator	
	(a) Δ Investment	$ 1530
	(b) Δ Replacement	$ 0
	(c) Δ Salvage	$ 0
	(d) Denominator	$ 1530
(3)	SIR	5.43

Slide 18

Identifying Information

Building:

Location Washington, DC
DOE Region 3
Use Military Base Housing
Type Residential
Life 15 Years

Project Add R-11 to R-19 Attic Insulation
Project Life 15 Years
Study Period 15 Years

Slide 19

A. Energy Costs Without Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	100 MBtu (55.56 MBtu)	$16.89/MBtu	$1689.00 ($ 938.41)	11.07	$18,697 ($10,388)
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$18,697 ($10,388)

Slide 20

E. TLCC Without Retrofit

(1) PV Energy	$18,697 ($10,388)
(2) PV Investment	$ 0
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$18,697 ($10,388)

Slide 21

F. Energy Costs With Retrofit

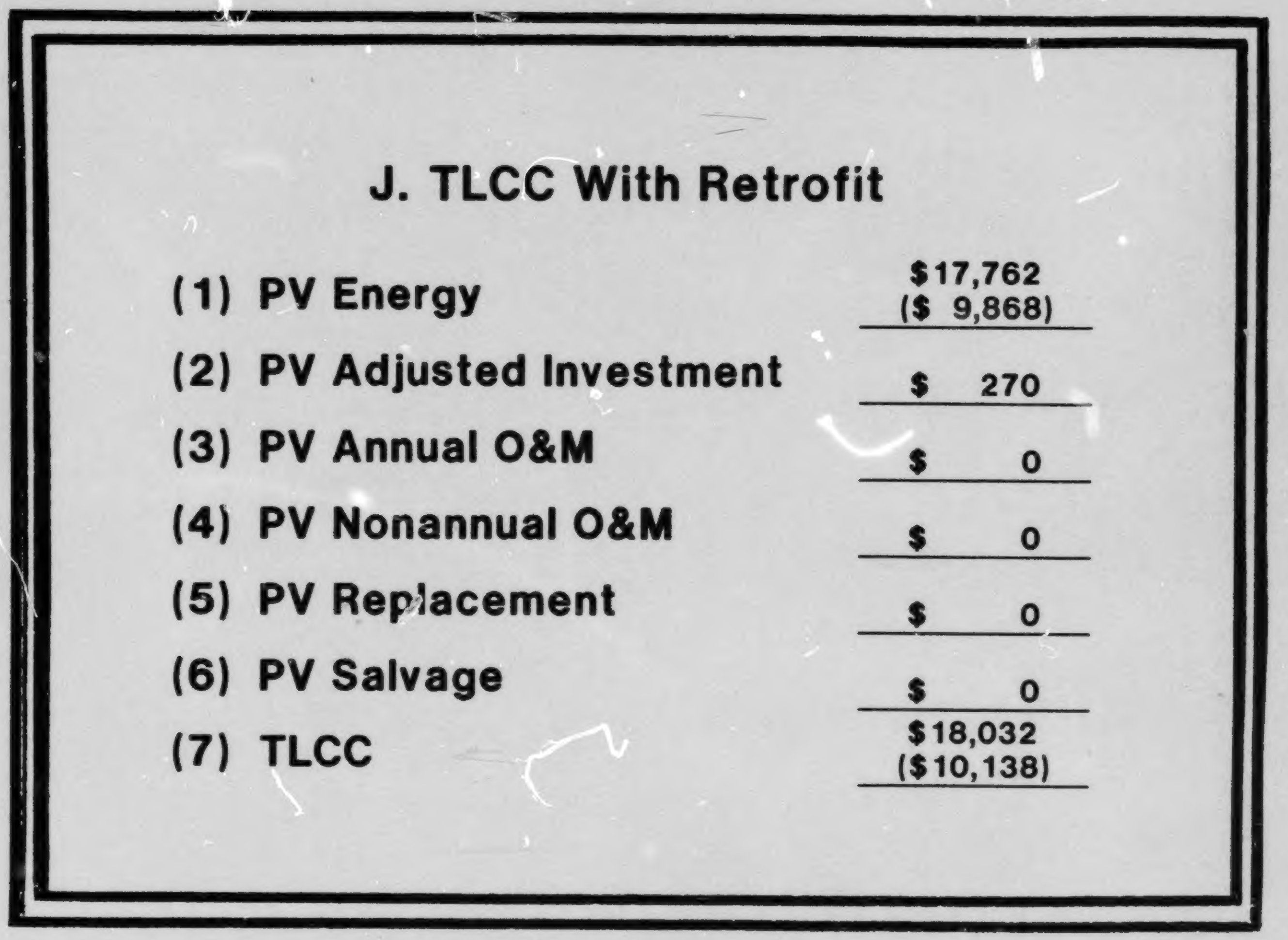
Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	95 MBtu (52.78 MBtu)	$16.89/MBtu	$1604.55 ($ 891.45)	11.07	$17,762 ($ 9,868)
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$17,762 ($ 9,868)

Slide 22

G. Investment Costs With Retrofit

(1) Actual Costs	$300
(2) Adjustment Factor	0.9
(3) Adjusted Costs	$270
(4) Renovation Costs	$ 0
(5) Adjusted PV	$270

Slide 23



J. TLCC With Retrofit

(1) PV Energy	$17,762 ($ 9,868)
(2) PV Adjusted Investment	$ 270
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$18,032 ($10,138)

Slide 24

K. Net Savings of Project

(1) TLCC Without	$18,697 ($10,388)
(2) TLCC With	$18,032 ($10,138)
(3) Net Savings	$ 665 ($ 250)

Slide 25

L. SIR

(1) Numerator	
(a) Δ Energy Cost	$935 ($520)
(b) Δ Nonfuel O&M	$ 0
(c) Numerator	$935 ($520)
(2) Denominator	
(a) Δ Investment	$270
(b) Δ Replacement	$ 0
(c) Δ Salvage	$ 0
(d) Denominator	$270
(3) SIR	3.46 (1.93)

Identifying Information

Building:

Location Washington, D.C.

DOE Region 3

Use Military Base Housing

Type Residential

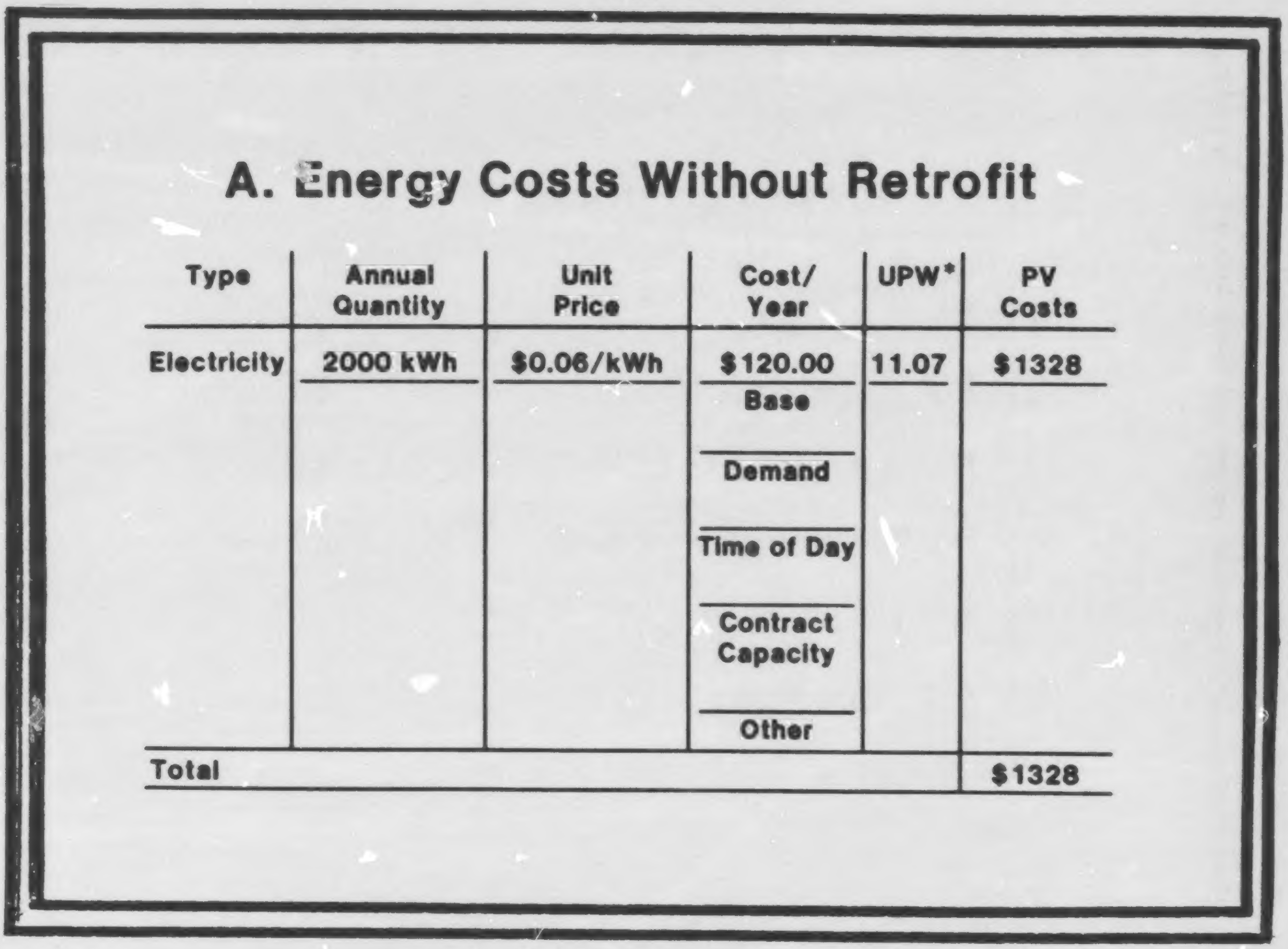
Life 15 Years

Project Install Fluorescent Lighting

Project Life 15 Years

Study Period 15 Years

Slide 27



A. Energy Costs Without Retrofit

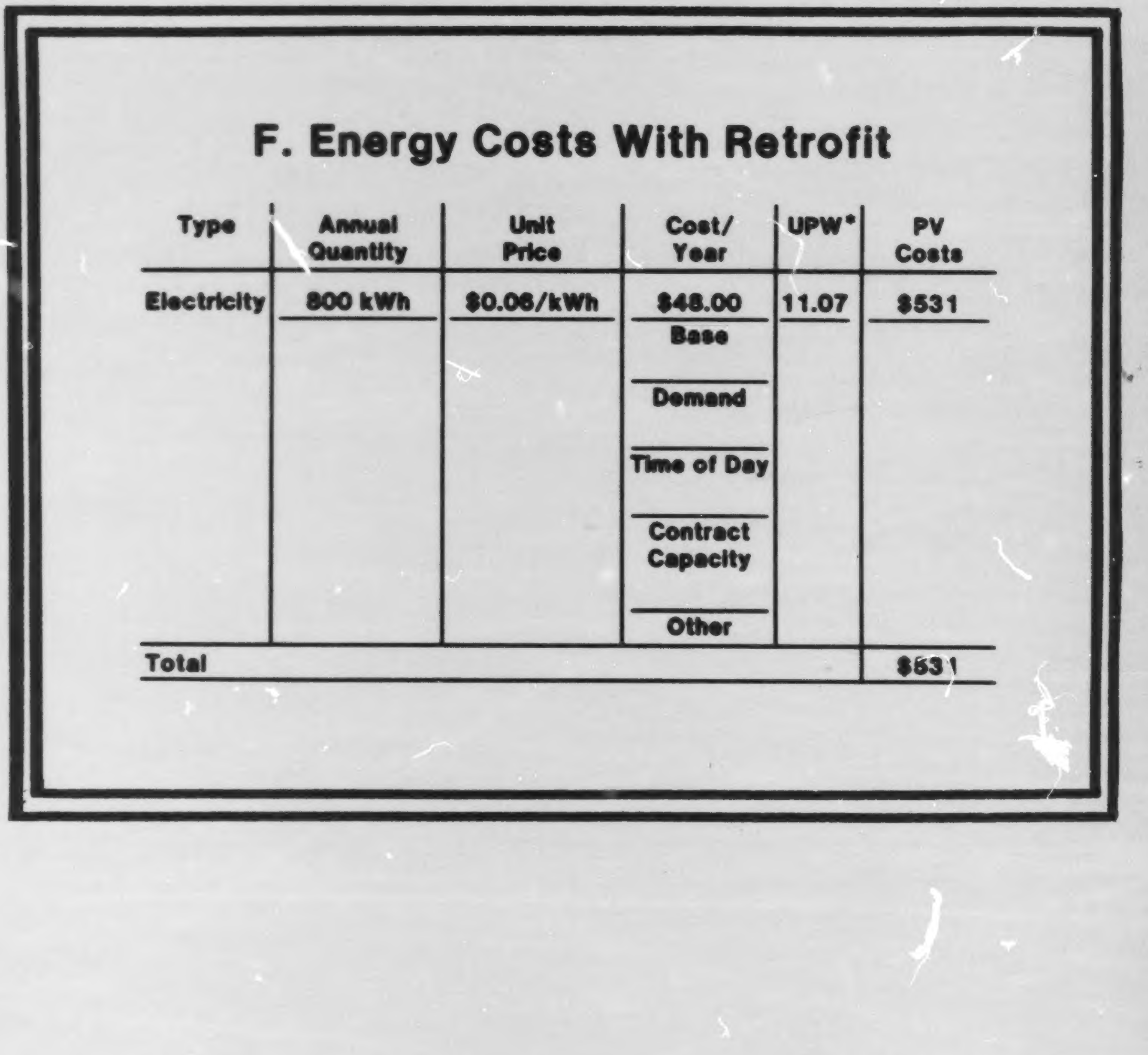
Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	2000 kWh	$0.06/kWh	$120.00 Base	11.07	$1328
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$1328

Slide 28

E. TLCC Without Retrofit

(1) PV Energy	$ 1328
(2) PV Investment	$ 0
(3) PV Annual O&M	$ 0
(4) PV Nonannual O&M	$ 0
(5) PV Replacement	$ 0
(6) PV Salvage	$ 0
(7) TLCC	$ 1328

Slide 29



F. Energy Costs With Retrofit

Type	Annual Quantity	Unit Price	Cost/ Year	UPW*	PV Costs
Electricity	800 kWh	$0.06/kWh	$48.00	11.07	$531
			Base		
			Demand		
			Time of Day		
			Contract Capacity		
			Other		
Total					$531

Slide 30

G. Investment Costs With Retrofit

(1) Actual Costs	$ 300
(2) Adjustment Factor	$ 0.9
(3) Adjusted Costs	$ 270
(4) Renovation Costs	$ 0
(5) Adjusted PV	$ 270

J. TLCC With Retrofit

(1)	PV Energy	$ 531
(2)	PV Adjusted Investment	$ 270
(3)	PV Annual O&M	$ 0
(4)	PV Nonannual O&M	$ 0
(5)	PV Replacement	$ 0
(6)	PV Salvage	$ 0
(7)	TLCC	$ 801

K. Net Savings of Project

(1) TLCC Without	$ 1328
(2) TLCC With	$ 801
(3) Net Savings	$ 527

Slide 33

L. SIR

(1) Numerator	
(a) Δ Energy Cost	$ 797
(b) Δ Nonfuel O&M	$ 0
(c) Numerator	$ 797
(2) Denominator	
(a) Δ Investment	$ 270
(b) Δ Replacement	$ 0
(c) Δ Salvage	$ 0
(d) Denominator	$ 270
(3) SIR	2.95

PROJECT SELECTION

PROJECT	PROJECT COST ($)	SIR	NET SAVINGS ($)	SELECTION
Heat pump	1700	5.43	6,779	X
Insulation without HP	300	3.46	665	
Lighting	300	2.95	527	X
Solar water heater	1600	2.28	1850	
Insulation with HP	300	1.93	250	

Section 15

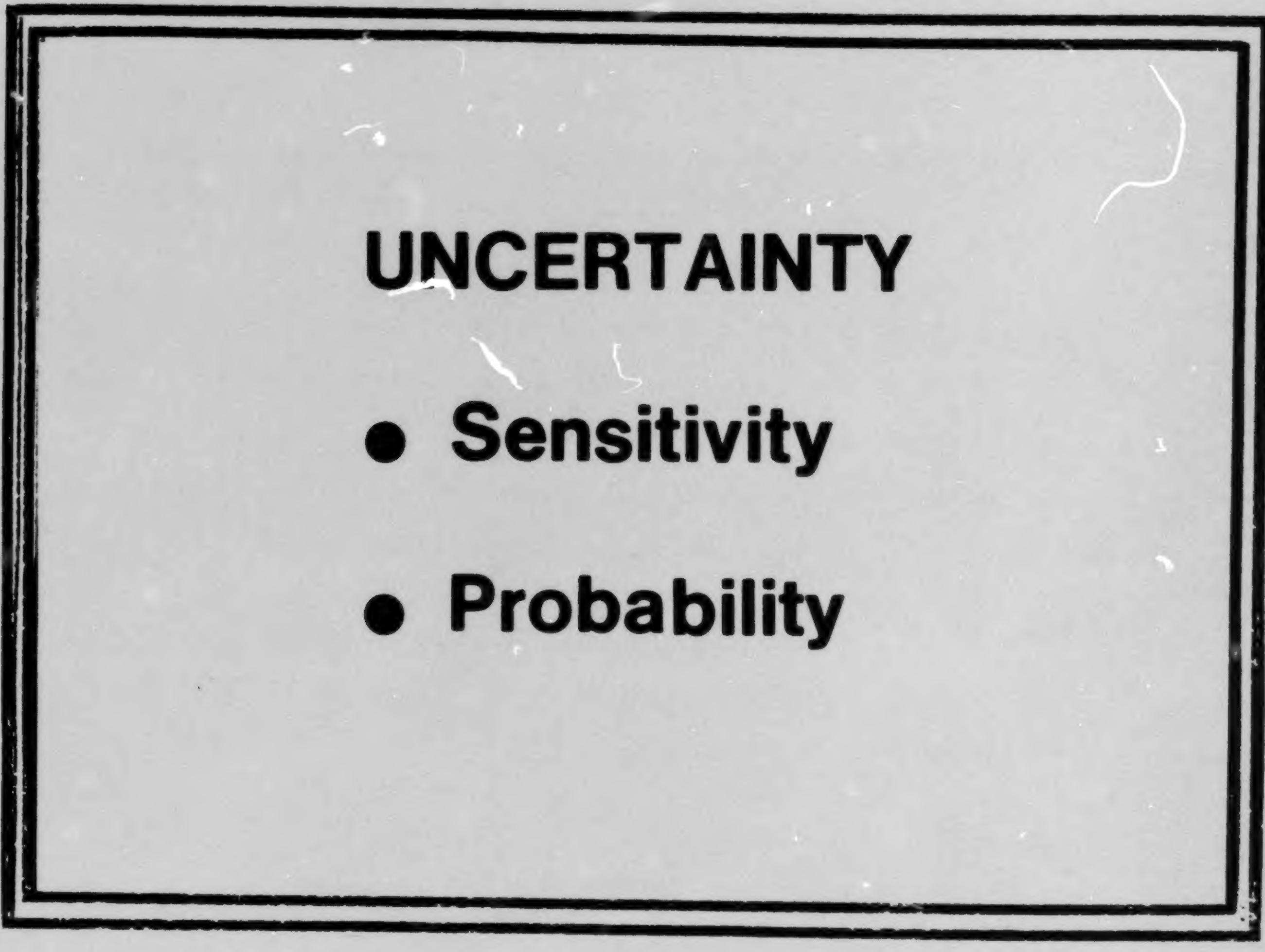
Slide Presentation: Sensitivity Analysis

The purpose of the sessions on sensitivity analysis and probability analysis is to present techniques for dealing with uncertainty in project evaluation.

The lecture material for this session is provided in the corresponding sections of the Workbook. The sensitivity and probability analysis problems from Problem Set C in the Workbook can be assigned as class problems following the counterpart lecture, or one or both of them can be incorporated in the lecture to reduce the time required to cover the material.

228

Slide 1



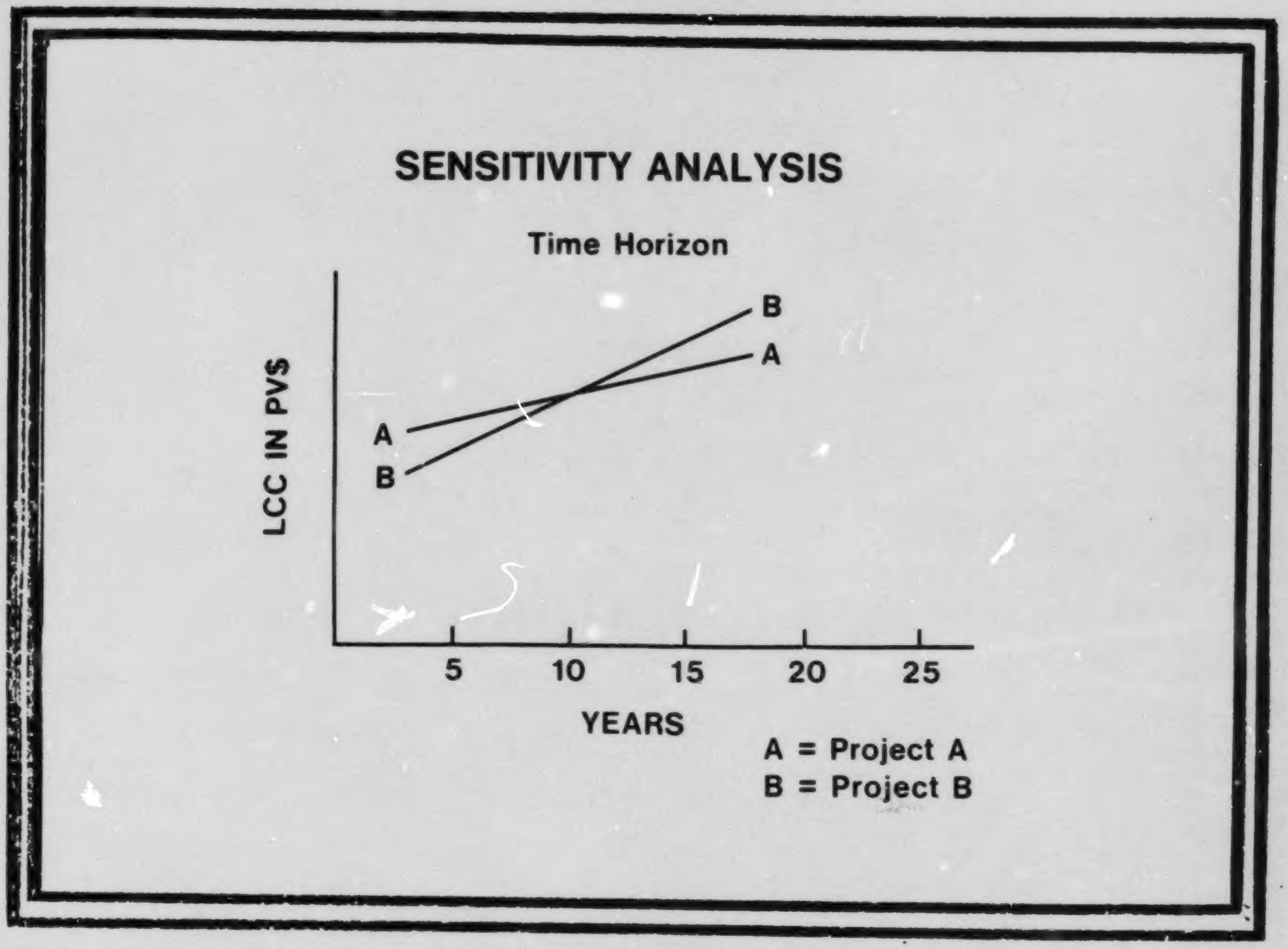
UNCERTAINTY

- Sensitivity
- Probability

Uncertainty

- Introduce the topic of uncertainty.
- Contrast the implied assumption of certainty in the preceding problems with real world conditions.
- Refer the class to Section 6 of the Workbook, Sensitivity Analysis, and discuss the material presented there.

Slide 2



SENSITIVITY ANALYSIS

Time Horizon

A = Project A
B = Project B

Sensitivity Analysis

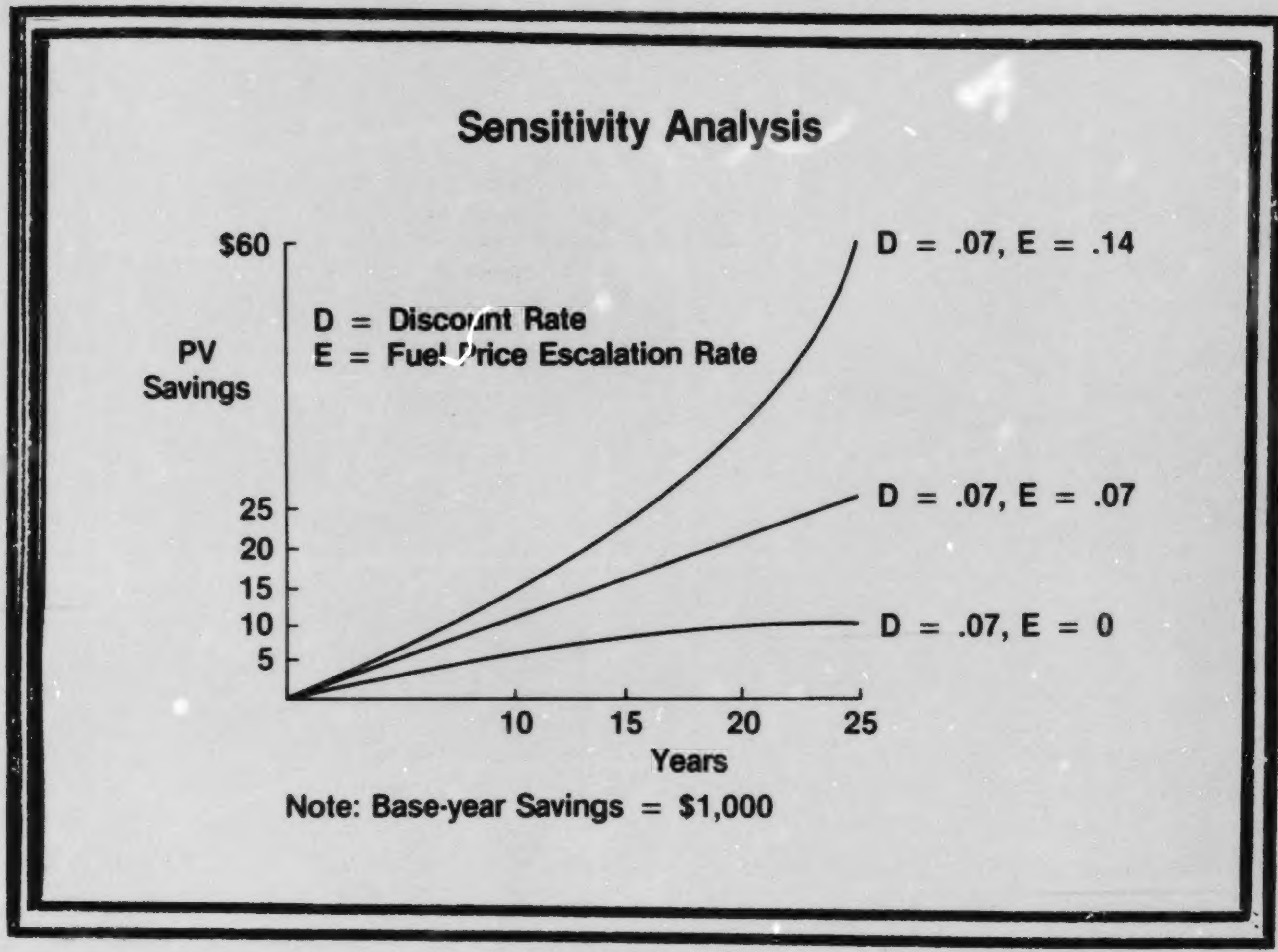
- Explain that graphical displays are often useful for portraying uncertainty.

- Discuss the graph shown in the slide, labeling the axes, and explaining that the cost-effective choice between projects A and B is sensitive to the length of time over which the project will be needed.

- Ask the class which project would be more cost effective if it were needed only 5 years.

- Ask which would be more cost effective if it were needed for 20 years.

Slide 3



Sensitivity Analysis

Note: Base-year Savings = $1,000

Sensitivity Analysis

- Explain that this slide illustrates the sensitivity of estimated present value energy savings to the escalation rate.

- Also point out that the estimated life becomes more important the higher the escalation rate.

Sensitivity Analysis Problem: Insulation

[Note: This is a hypothetical example intended only to illustrate the technique.]

Problem Description: Assume that you, as a homeowner, wish to insulate your attic, which is currently uninsulated, to reduce your electricity cost. The house is heated by an electric resistance system and the current price of electricity is $.057/kWh ($16.77/10^6Btu). You expect to remain in the house another 25 years. Your best alternative use of the money you have available to spend on insulating the house is for a tax-free bond paying 10% compounded annually. Current inflation is about 3% per year. The house is located in Washington, D.C.

Using the Means Building Construction Cost Data Guide you find the following cost data for this area for fiberglass batts:

	Material Cost ($/ft^2)	Labor ($/ft^2)	Overhead and Profit (Multiplier)
R-11	.14	.06	1.25
R-19	.24	.07	1.23
R-30	.40	.08	1.17
R-38	.55	.09	1.15

In the past you have occasionally seen a 50% sale on installed insulation. However, you haven't seen any sales recently and do not know if the lower price will be available.

Furthermore, you have noted a recent upswing in the local building industry which may have driven labor rates sharply higher--as much as double those reported by Means.

The area to be insulated is 1,200 ft^2. You are basing your energy savings on DoE-projected price increases in energy, and on a recent research report by the National Bureau of Standards which estimated the annual savings from attic insulation for a house similar to yours as follows:

	Change in Annual Heating Requirements (10^6Btu)
O-R-11	12.913
O-R-19	14.987
O-R-30	16.315
O-R-38	16.833

Determine: How sensitive is the optimal level of attic insulation to these potential variations in costs.

Slide 1

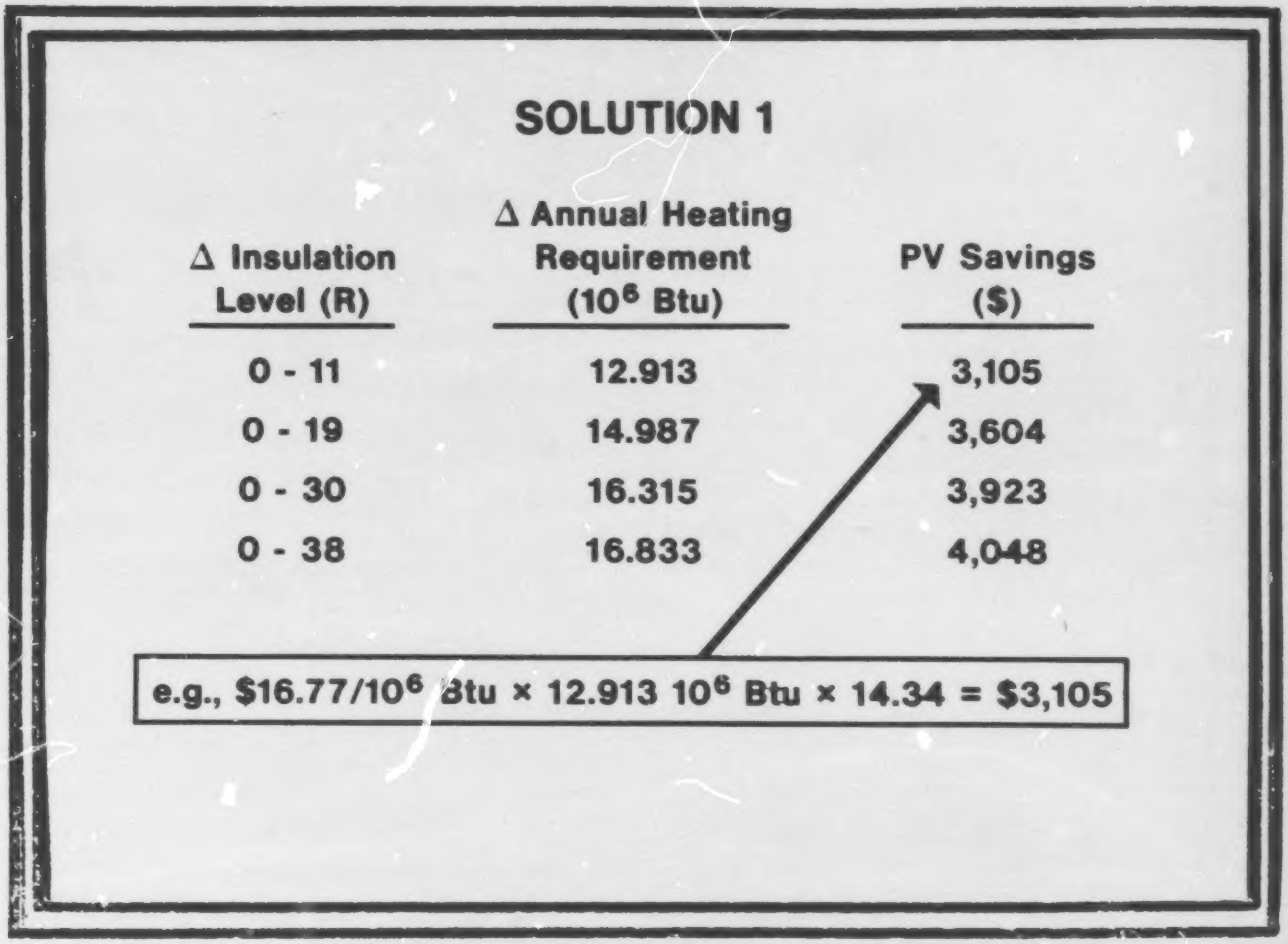
SENSITIVITY ANALYSIS — INSULATION PROBLEM

Sensitivity Analysis -- Insulation Problem

- Review the sensitivity problem statement.
- Ask the class to solve the problem or to follow along with the solution presented.

233

Slide 2



SOLUTION 1

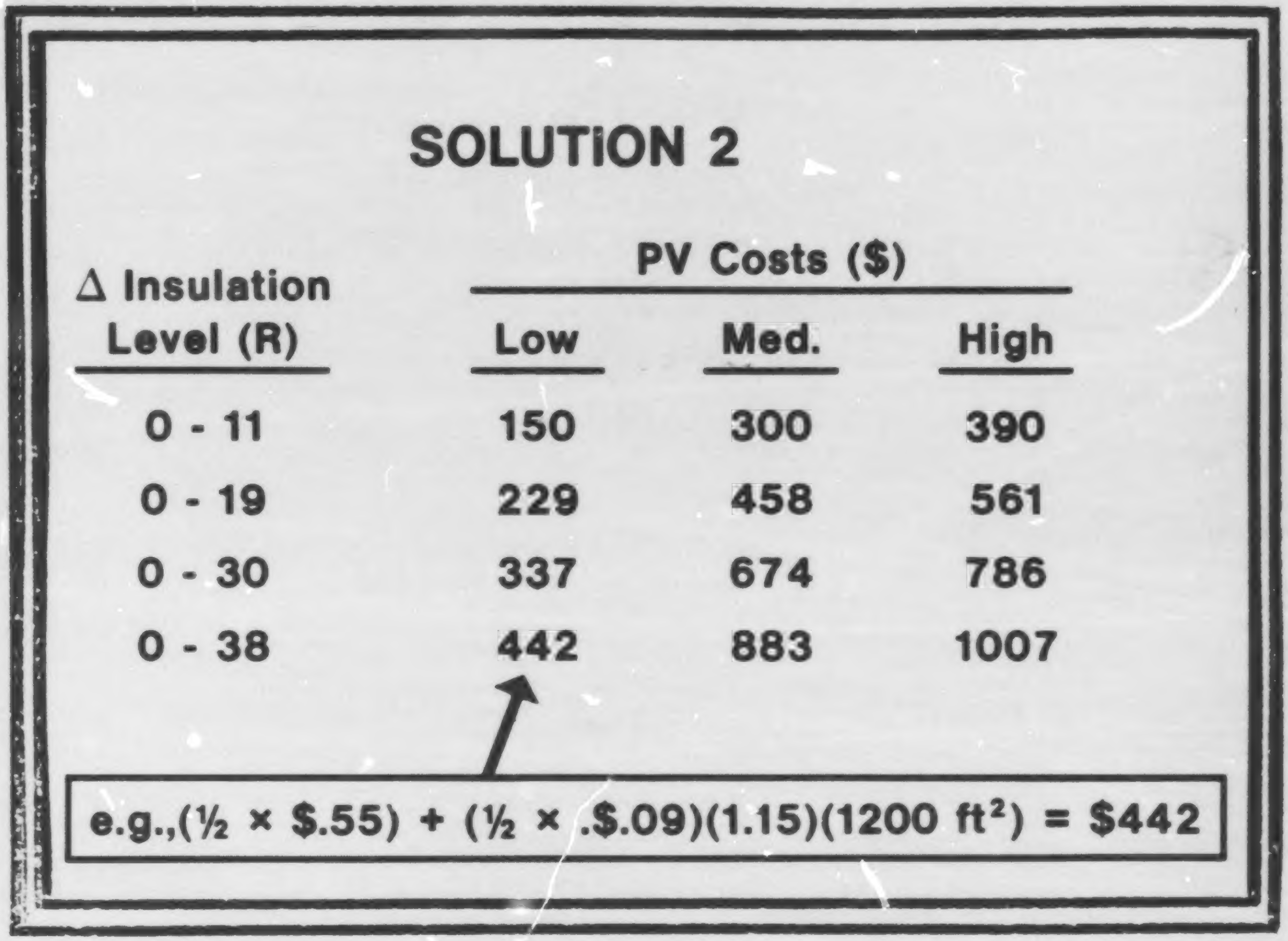
Δ Insulation Level (R)	Δ Annual Heating Requirement (10^6 Btu)	PV Savings ($)
0 - 11	12.913	3,105
0 - 19	14.987	3,604
0 - 30	16.315	3,923
0 - 38	16.833	4,048

e.g., $\$16.77/10^6\ \text{Btu} \times 12.913\ 10^6\ \text{Btu} \times 14.34 = \$3{,}105$

Solution 1

- o Explain the calculation of present value savings, working through the calculation for R-11.

Slide 3



SOLUTION 2

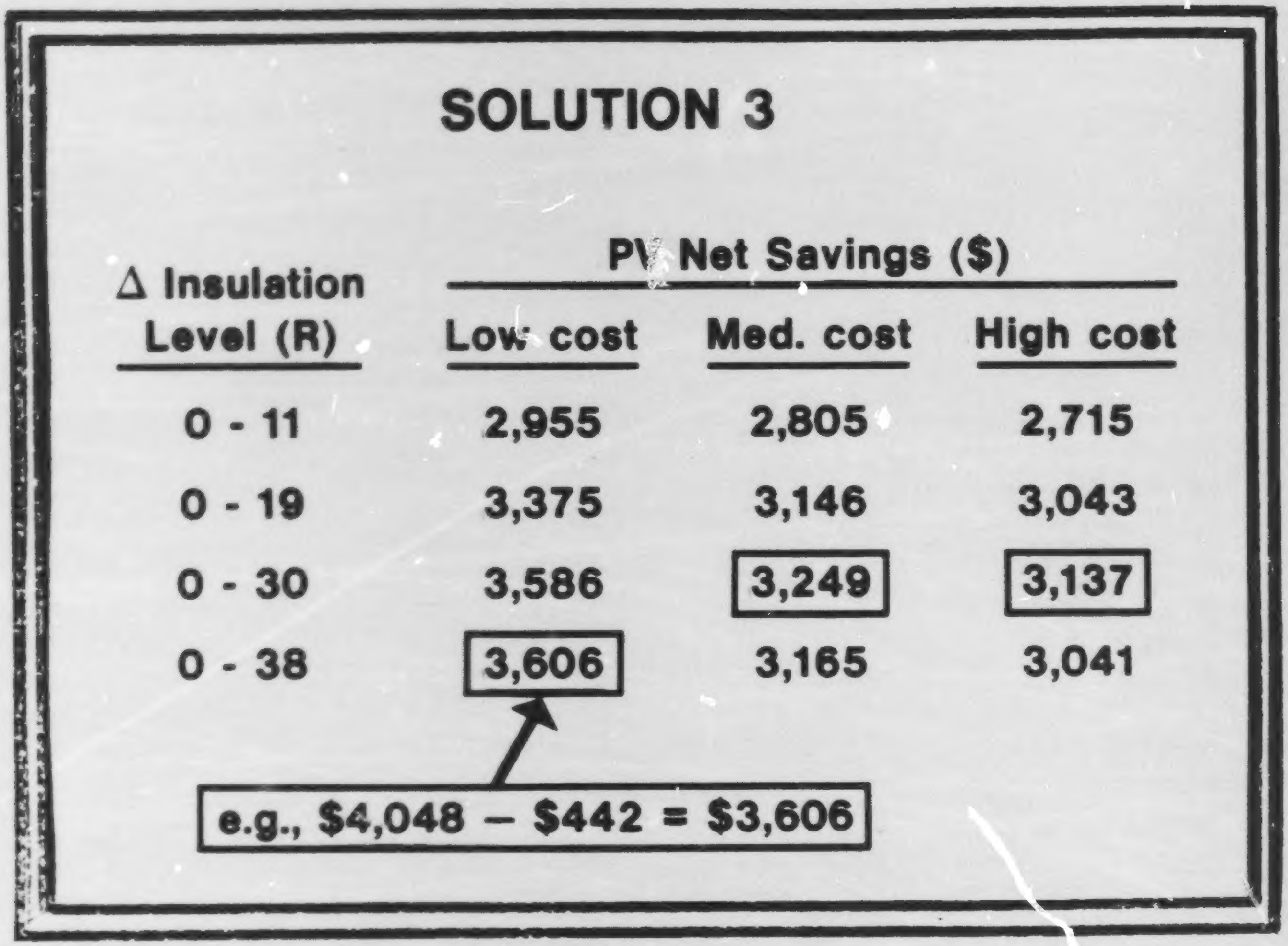
Δ Insulation Level (R)	PV Costs ($)		
	Low	Med.	High
0 - 11	150	300	390
0 - 19	229	458	561
0 - 30	337	674	786
0 - 38	442	883	1007

$\text{e.g.,}(\tfrac{1}{2} \times \$.55) + (\tfrac{1}{2} \times .\$.09)(1.15)(1200\ \text{ft}^2) = \$442$

Solution 2

- Explain the calculation of costs, working through the calculation for R-38.

Slide 4



SOLUTION 3

Δ Insulation Level (R)	PV Net Savings ($)		
	Low cost	Med. cost	High cost
0 - 11	2,955	2,805	2,715
0 - 19	3,375	3,146	3,043
0 - 30	3,586	3,249	3,137
0 - 38	3,606	3,165	3,041

e.g., \$4,048 – \$442 = \$3,606

Solution 3

- o Explain the calculation of net savings, working through the calculation for R-38.
- o Discuss the results.

Section 17

Slide Presentation: Probability Analysis

The lecture material for this session is provided in the corresponding section of the seminar Workbook. Explain the technique, list the steps, and then illustrate the technique primarily through the example.

Slide 1

PROBABILITY ANALYSIS - APPROACH

1. List courses of action
2. List possible states
3. Evaluate outcome for each course of action and state
4. Search for dominance
5. Assign probabilities
6. Calculate expected values
7. Choose course of action

Probability Analysis -- Approach

- Review the 7 steps in the approach.

Slide 2

EXPECTED VALUE CALCULATION

$$EV_A = p_1 x_{A1} + p_2 x_{A2} + \ldots p_n x_{An}$$

Expected Value Calculation

- o Explain the calculation of expected value.

Problem Illustration--Calculating Expected Values

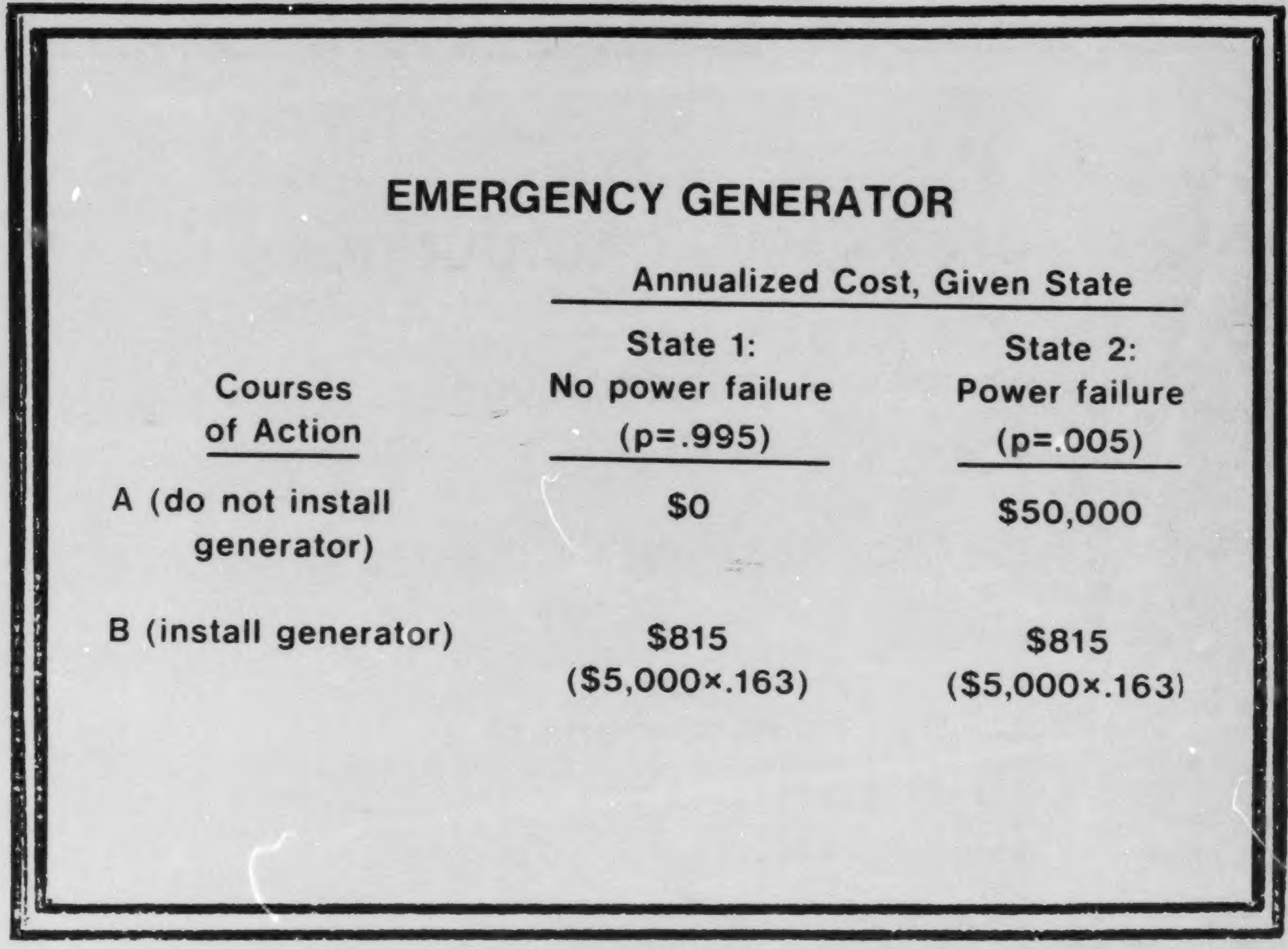
[Note: This is a hypothetical problem intended only to illustrate the technique.]

The problem is whether or not to install an emergency power generator for refrigerated storage in a Federal warehouse facility. The generator costs $5,000 to purchase and install, and is expected to have no other significant costs over its estimated 10 year life. Two courses of action are to be considered: Course A, do not install the generator; and Course B, install the generator.

The rationale for installing the emergency generator is to protect against losses of stored goods which will result if there is a power failure lasting more than four hours. Based on past experience, the electric utility predicts the probability of a single occurrence within the period of a year of power failure exceeding four hours to be .005. The Federal agency estimates the value of losses per event of major power failure to be $50,000 without the generator, and $0 with the generator.

The decision maker wishes to make the decision on the basis of minimizing the expected value of the overall cost of the operation. Should the generator be installed? (Assume that a 10 percent discount rate applies.)

Slide 3



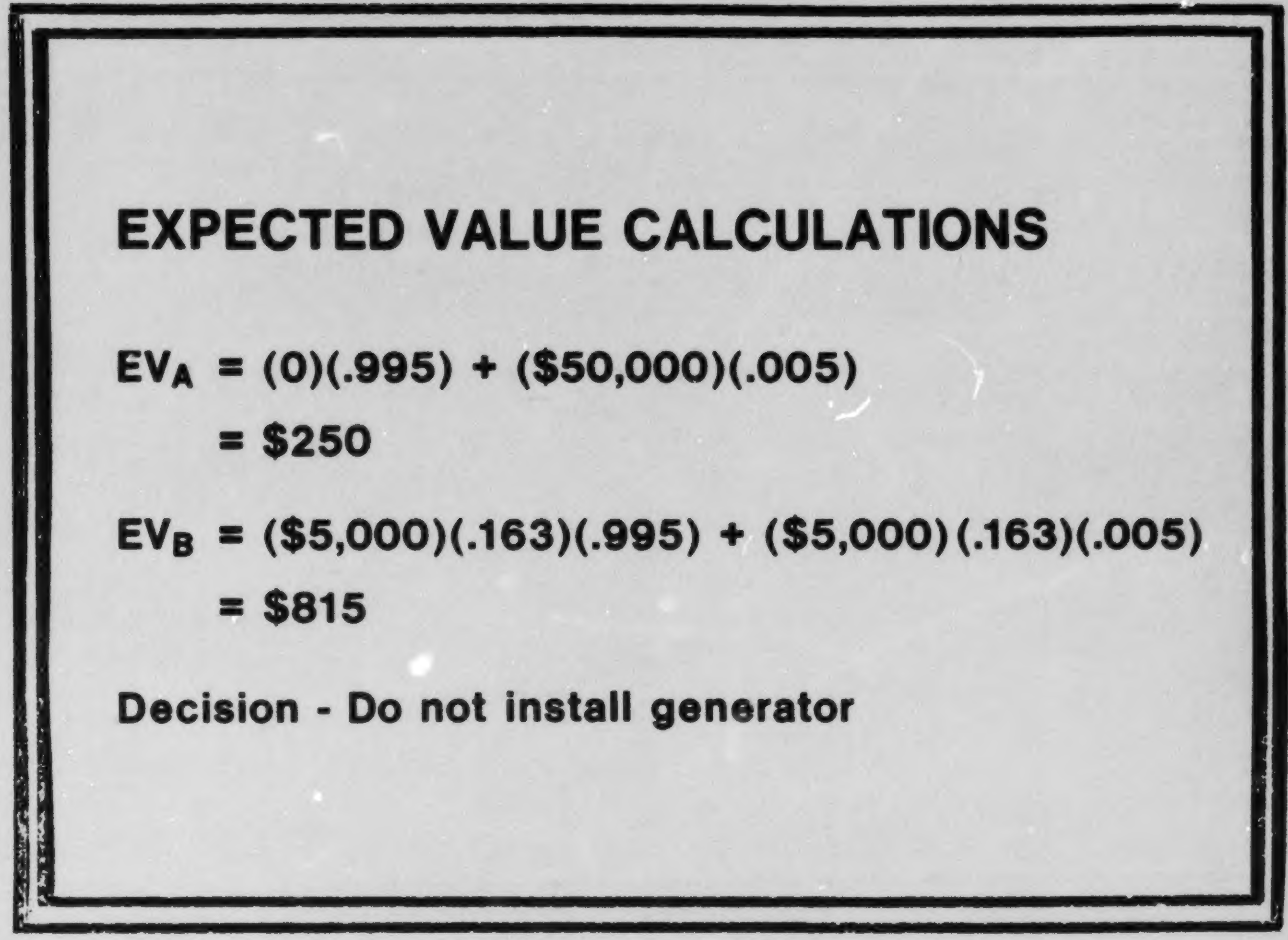
EMERGENCY GENERATOR

	Annualized Cost, Given State	
Courses of Action	State 1: No power failure (p=.995)	State 2: Power failure (p=.005)
A (do not install generator)	$0	$50,000
B (install generator)	$815 ($5,000×.163)	$815 ($5,000×.163)

Emergency Generator

- Refer the class to the "Emergency Generator" Problem Illustration in the Workbook section on Probability Analysis, noting the step-by-step solution.
- Go through each of the first five steps, referring to the relevant information on the slide.

Slide 4



EXPECTED VALUE CALCULATIONS

$EV_A = (0)(.995) + (\$50{,}000)(.005)$

$= \$250$

$EV_B = (\$5{,}000)(.163)(.995) + (\$5{,}000)(.163)(.005)$

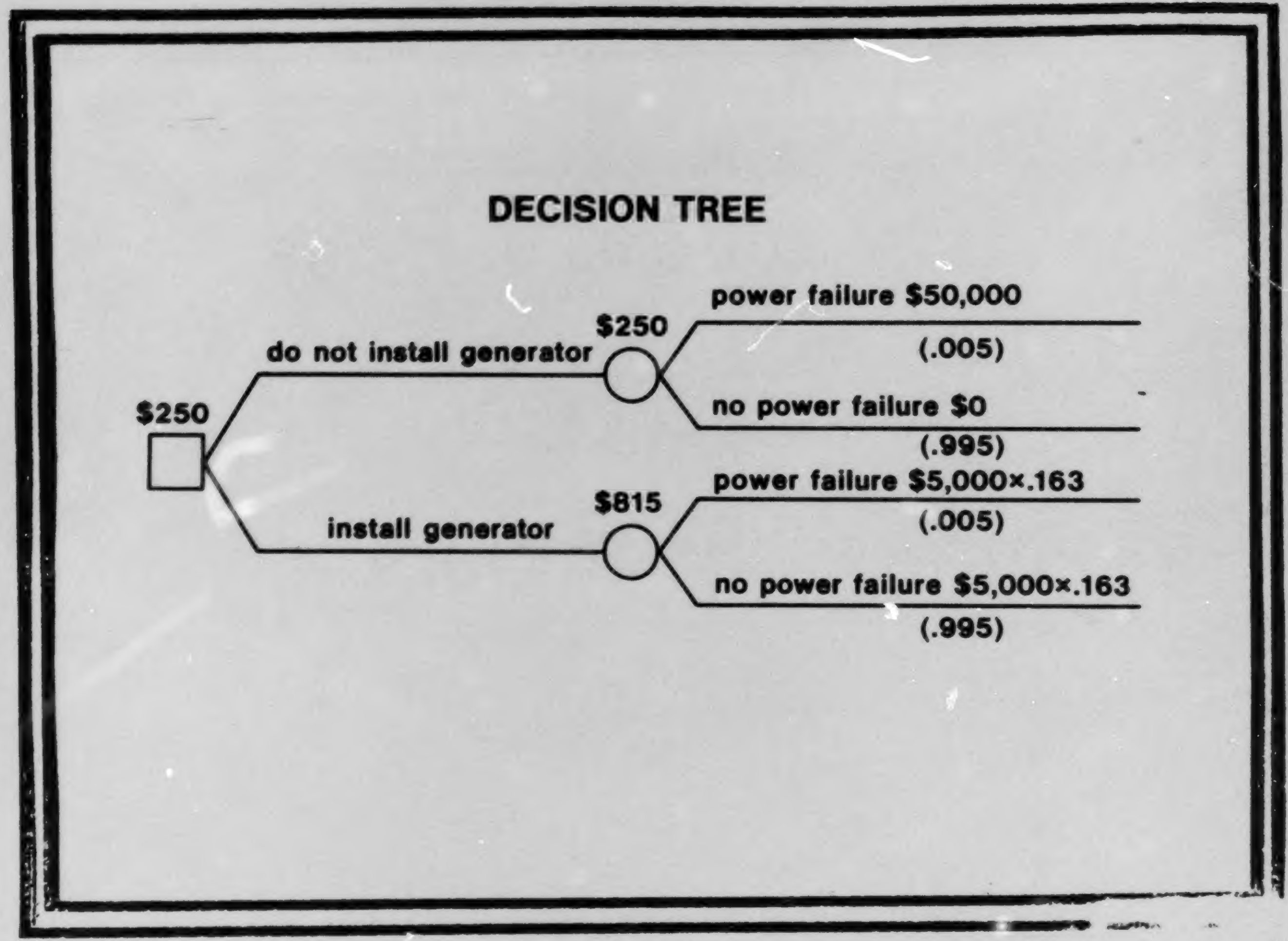
$= \$815$

Decision - Do not install generator

Expected Value Calculations

- Explain the expected value calculations.
- Ask what the decision would be based on expected value analysis.
- Discuss the conditions under which expected values are generally acceptable for decision making and conditions under which the approach may not be an acceptable decision criterion.
- It may be useful to discuss risk preferences and utility theory.

Slide 5


DECISION TREE
$250
do not install generator
$250
power failure $50,000
(.005)
no power failure $0
(.995)
install generator
$815
power failure $5,000×.163
(.005)
no power failure $5,000×.163
(.995)

Decision Tree

- o Explain the use of decision trees in probability analysis, based on the material provided in the Workbook.

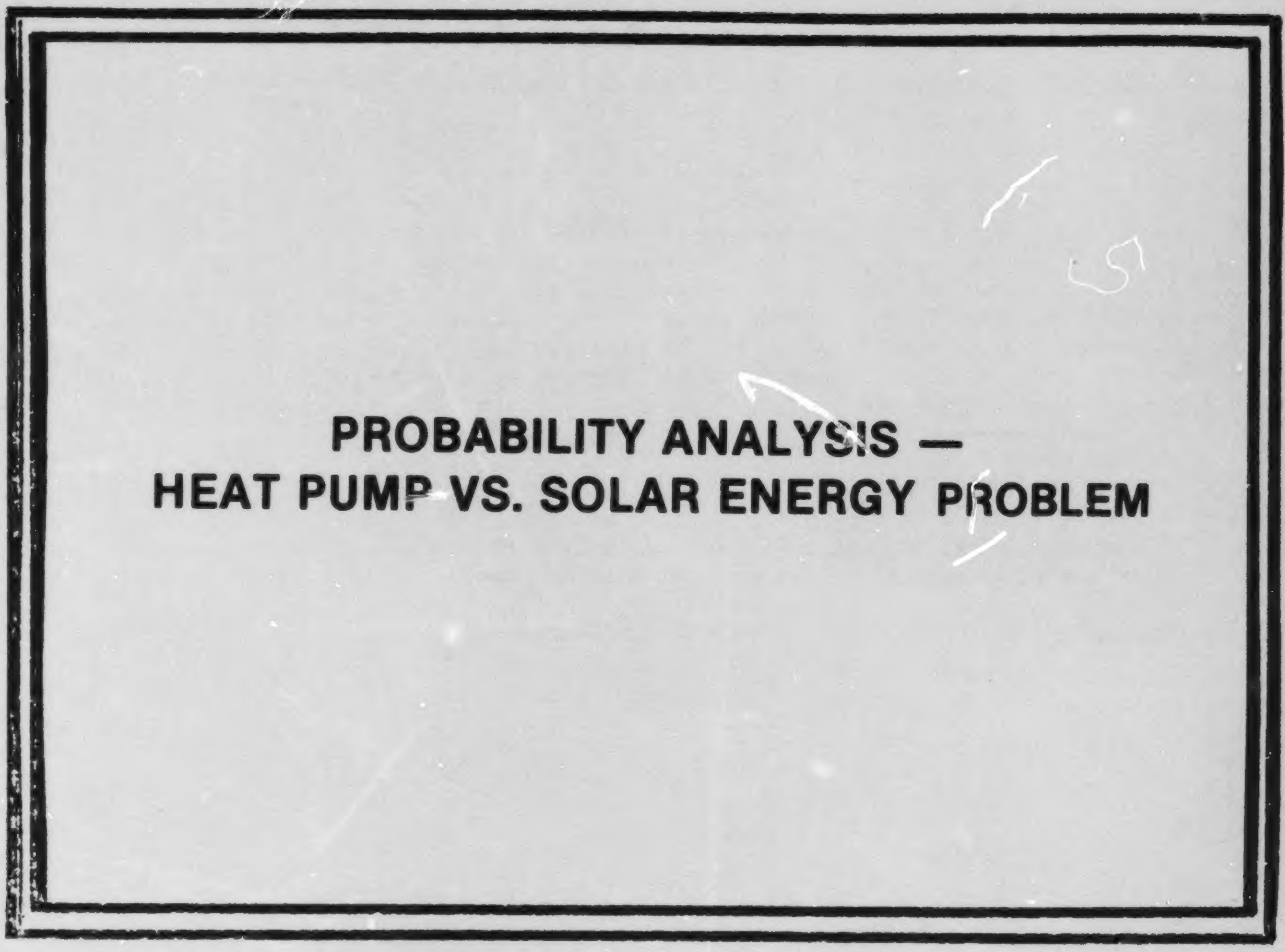
Section 18

Problem in Probability Analysis: Heat Pump Versus Solar Energy System

[Note: This is a hypothetical problem intended only to illustrate the technique.]

A heat pump and a solar energy system are two alternatives being considered for retrofit to a number of similar Federal facilities. If the solar energy system is installed, the existing heating system will be used as an auxiliary system. The heat pump requires no auxiliary system. A major area of concern is whether or not the existing system will provide reliable auxiliary service without major overhaul costs. Expert judgment is that there is about a 30 percent chance that the existing system in a given facility will be found to require major overhaul in order to provide auxiliary service to the solar energy system, and a 70 percent chance that no major repairs or modifications will be needed. If no major overhaul is needed, the combined life-cycle cost of the solar/auxiliary system is estimated at $20,000; and if major overhaul is needed, at $35,000. The life-cycle cost of the heat pump is estimated at $25,000. Which system do you recommend on the basis of minimizing the expected value of the life-cycle cost?

Slide 1



PROBABILITY ANALYSIS — HEAT PUMP VS. SOLAR ENERGY PROBLEM

Probability Analysis -- Heat Pump vs. Solar Energy Problem

- Ask the class to solve the problem, incorporate it in the presentation, or omit it if the preceding problem illustration was adequate for class understanding.

SOLUTION

Course of Action	PV Cost State 1: No Overhaul (p = .7)	State 2: Overhaul (p = .3)
A (install heat pump)	$25,000	$25,000
B (install solar)	$20,000	$35,000

Slide 3

EXPECTED VALUE

$EV_A = \$25{,}000$

$$EV_B = (\$20{,}000)(.7) + (35{,}000)(.3)$$
$$= \$24{,}500$$

Expected Value

- Review results.

Section 19

Slide Presentation: Break-Even Analysis

This session is based on Section 8 of the Workbook. Explain the approach and discuss the different kinds of uses. Then illustrate the technique by presenting the sample problem.

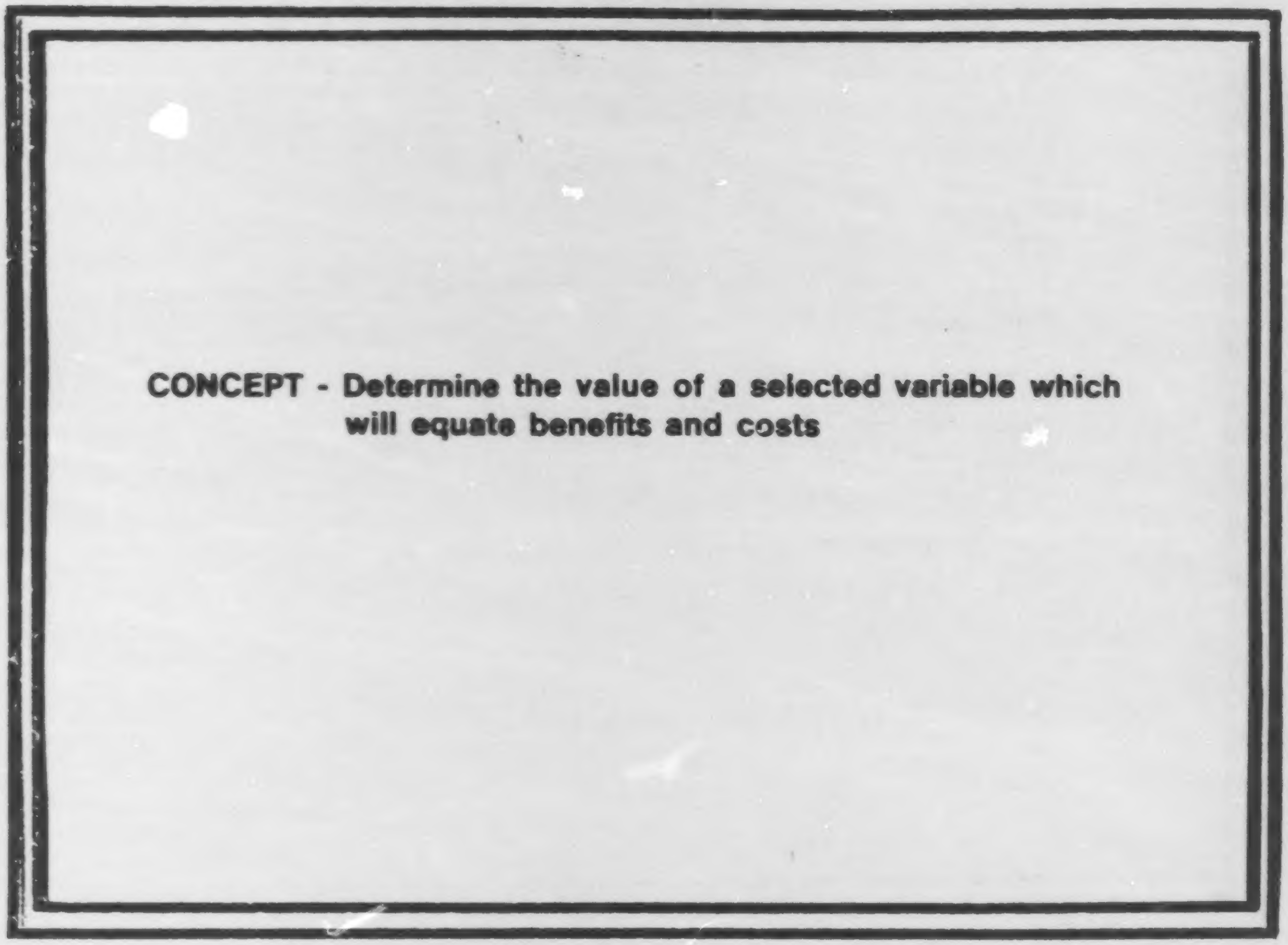
Slide 1

BREAK-EVEN ANALYSIS

Break-Even Analysis

- o Present the introduction.

Slide 2

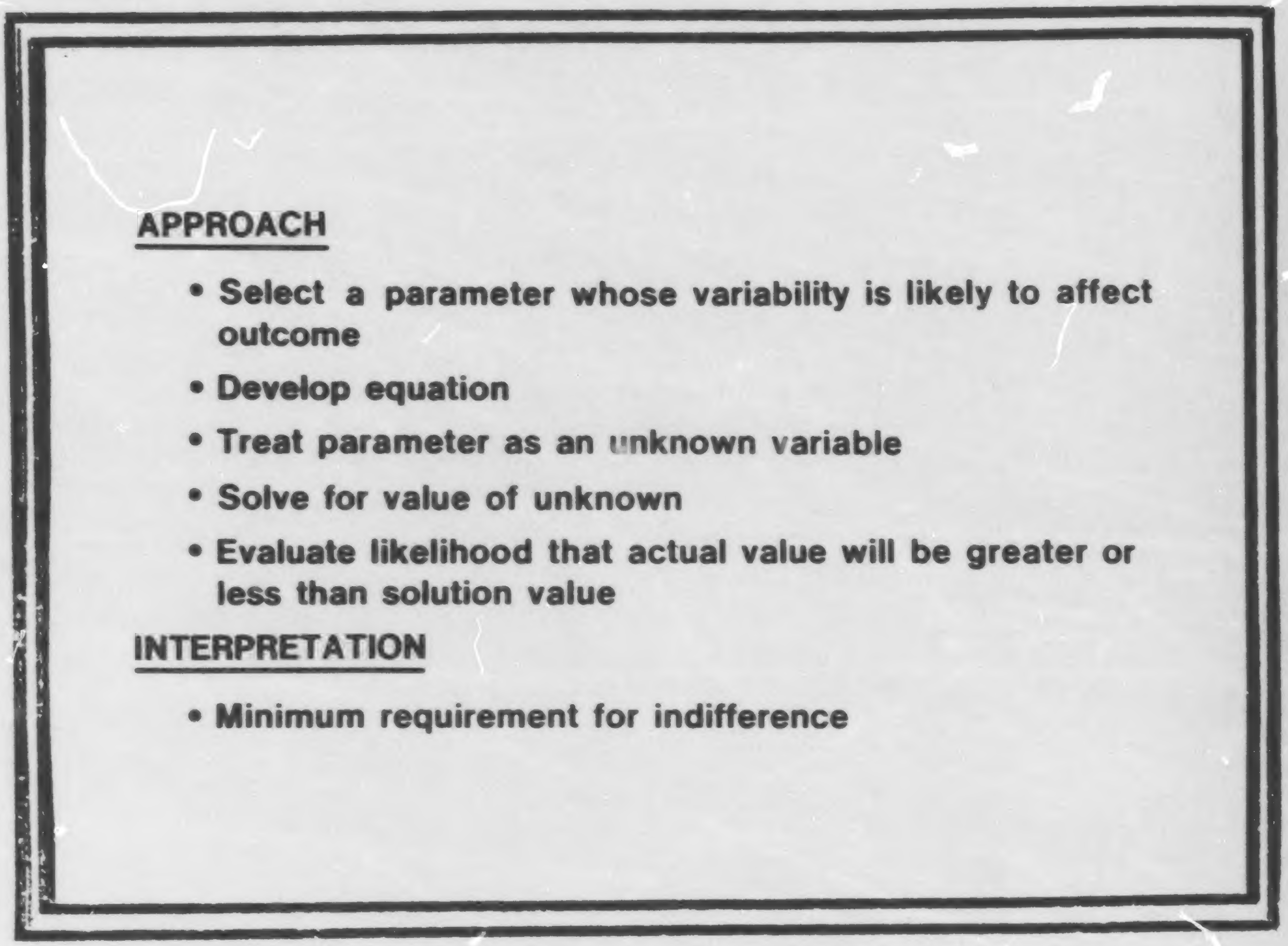


CONCEPT - Determine the value of a selected variable which will equate benefits and costs

Concept

- o Discuss the concept.

Slide 3



APPROACH

- Select a parameter whose variability is likely to affect outcome
- Develop equation
- Treat parameter as an unknown variable
- Solve for value of unknown
- Evaluate likelihood that actual value will be greater or less than solution value

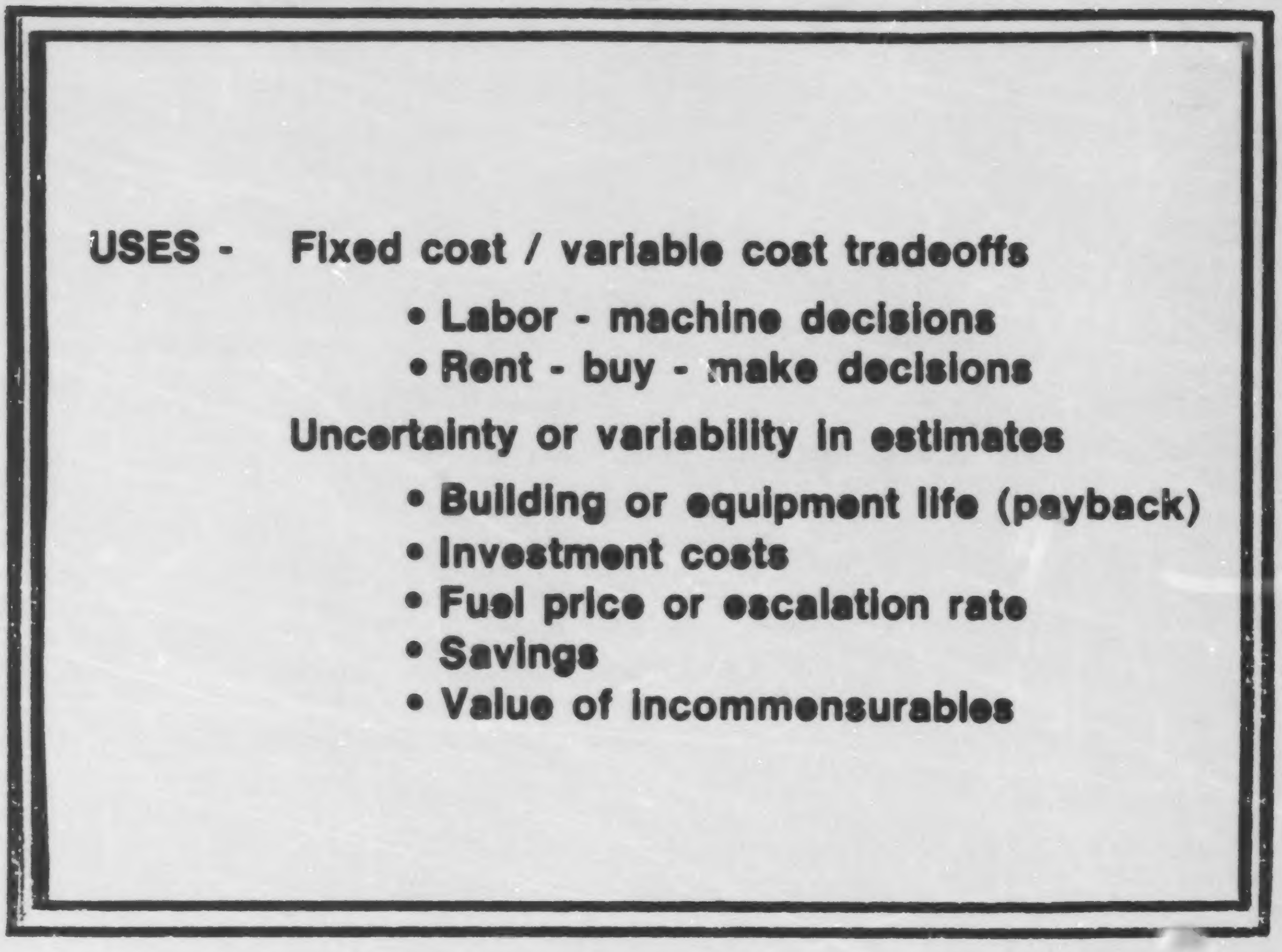
INTERPRETATION

- Minimum requirement for indifference

Approach/Interpretation

o Discuss the approach and interpretation of results.

Slide 4



USES - Fixed cost / variable cost tradeoffs

- Labor - machine decisions
- Rent - buy - make decisions

Uncertainty or variability in estimates

- Building or equipment life (payback)
- Investment costs
- Fuel price or escalation rate
- Savings
- Value of incommensurables

Uses

o Give examples of how the technique is used.

Break-Even Analysis Problem Illustration: Make-Buy Decision

[Note: This hypothetical problem is intended only to illustrate the technique.]

Problem Statement: A temporary Federal facility in Pennsylvania, now in the planning stage, will have a demand for steam. But at this time only a very rough estimate of the quantity demanded is available.

An outside source has expressed interest in supplying the steam requirements at an initial price (PP) of $10.00 per Mlb of steam supplied at the building boundary, with a subsequent annual escalation of price equal to the annual change in the GNP price deflator index plus 5 percent. The source appears reliable and compatible with other aspects of the facility's plan.

Preliminary estimates of the administrative, space, equipment, and maintenance costs required for in-house production are as follows:

Allocated Space (S): $20,000
Administrative (A): $10,000/yr.
Equipment, Purchase and Installation (E): $200,000
Equipment, Maintenance (M): $5,000/yr.

(These are rough estimates because they are dependent to some extent on the quantity of steam to be generated which is not known at this time. However, the cost analyst thinks the cost estimates are relatively accurate because of the large element of fixed costs involved.)

Additional information required to determine the cost of in-house production is as follows:

Price of Coal per ton (PC): \$45.00

Anticipated Plant Efficiency (Eff): 65%

Required Length of Service (N): 8 years

Anticipated Salvage at the End of 8 Years ($\overline{S}$): 0

Btu Content per Thousand Pounds (Mlb) of Steam: 1.05×10^6Btu

Btu Content per Ton of Coal: 22.5×10^6Btu

The facility planners are trying to decide whether to recommend that the steam requirements be met through the outside supplier or by in-house production. They believe life-cycle cost differences should be the deciding factor. However, they are having difficulty with this comparison due to the uncertainty regarding the amount of steam that will be demanded.

To do:

Assist them with their decision by estimating the minimum quantity of annual steam demand necessary for cost-effective in-house production.

Slide 5

PROBLEM: To meet steam demand

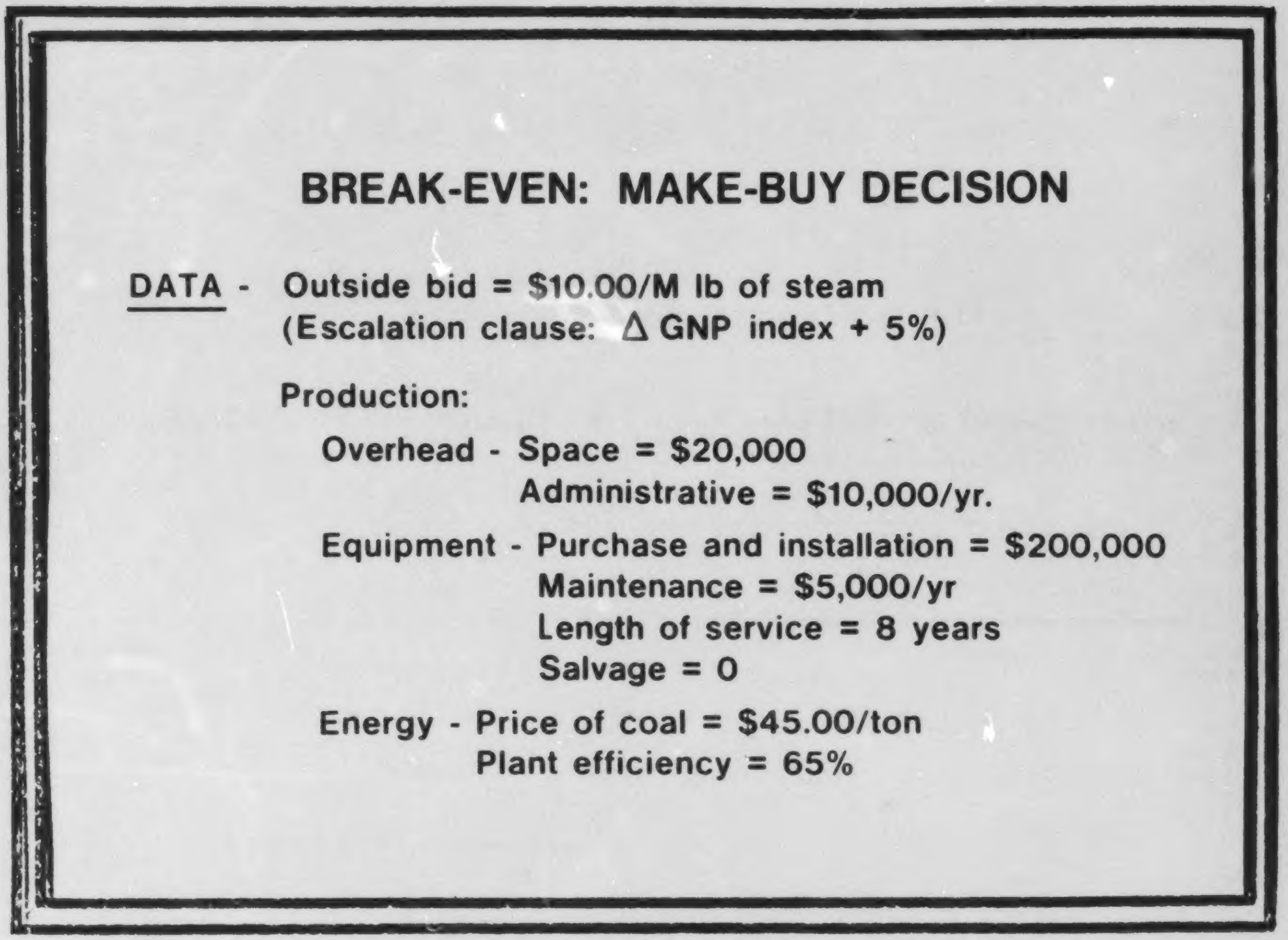
QUESTION: Make or Buy ?

CRITICAL FACTOR: Quantity demanded

Problem/Question/Critical Factor

- Refer the class to the problem illustration in the section of the Workbook on break-even analysis.
- Discuss the problem statement, and explain that you will go through the solution step-by-step.

Slide 6



BREAK-EVEN: MAKE-BUY DECISION

DATA - Outside bid = \$10.00/M lb of steam
(Escalation clause: Δ GNP index + 5%)

Production:

Overhead - Space = \$20,000
Administrative = \$10,000/yr.

Equipment - Purchase and installation = \$200,000
Maintenance = \$5,000/yr
Length of service = 8 years
Salvage = 0

Energy - Price of coal = \$45.00/ton
Plant efficiency = 65%

Break-Even: Make-Buy Decision

- Discuss problem formulation. Explain that the approach is to equate the cost of buying with the cost of on-site generation, leaving the quantity of steam unspecified. Then solve for the quantity of steam.

Slide 7

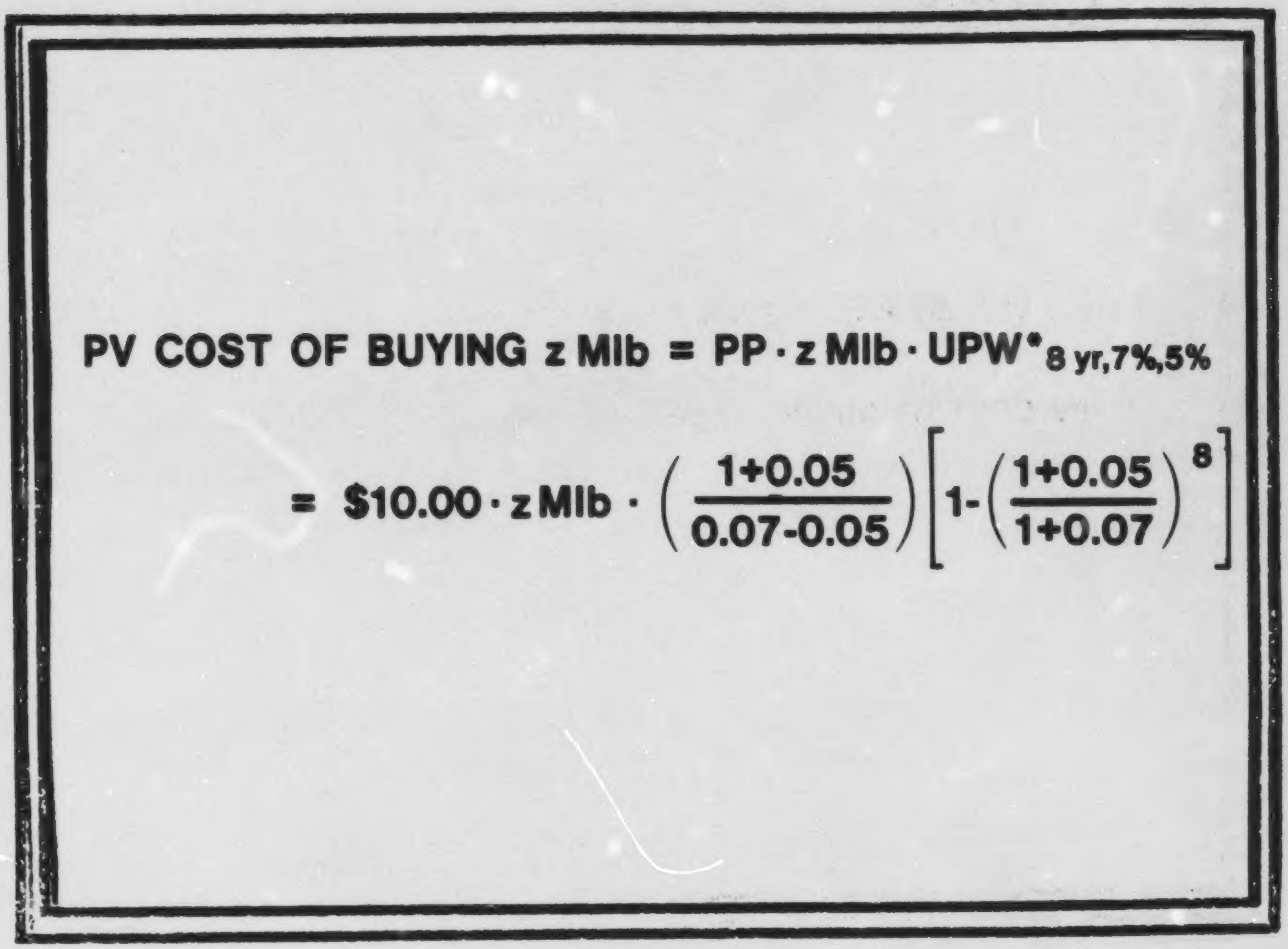
SOLVE FOR BREAK-EVEN QUANTITY (z Mlb) :

PV COST OF BUYING z Mlb = PV COST OF PRODUCING z Mlb

Solve for Break-Even Quantity (zMlb)

- Explain how the problem is formulated.

Slide 8



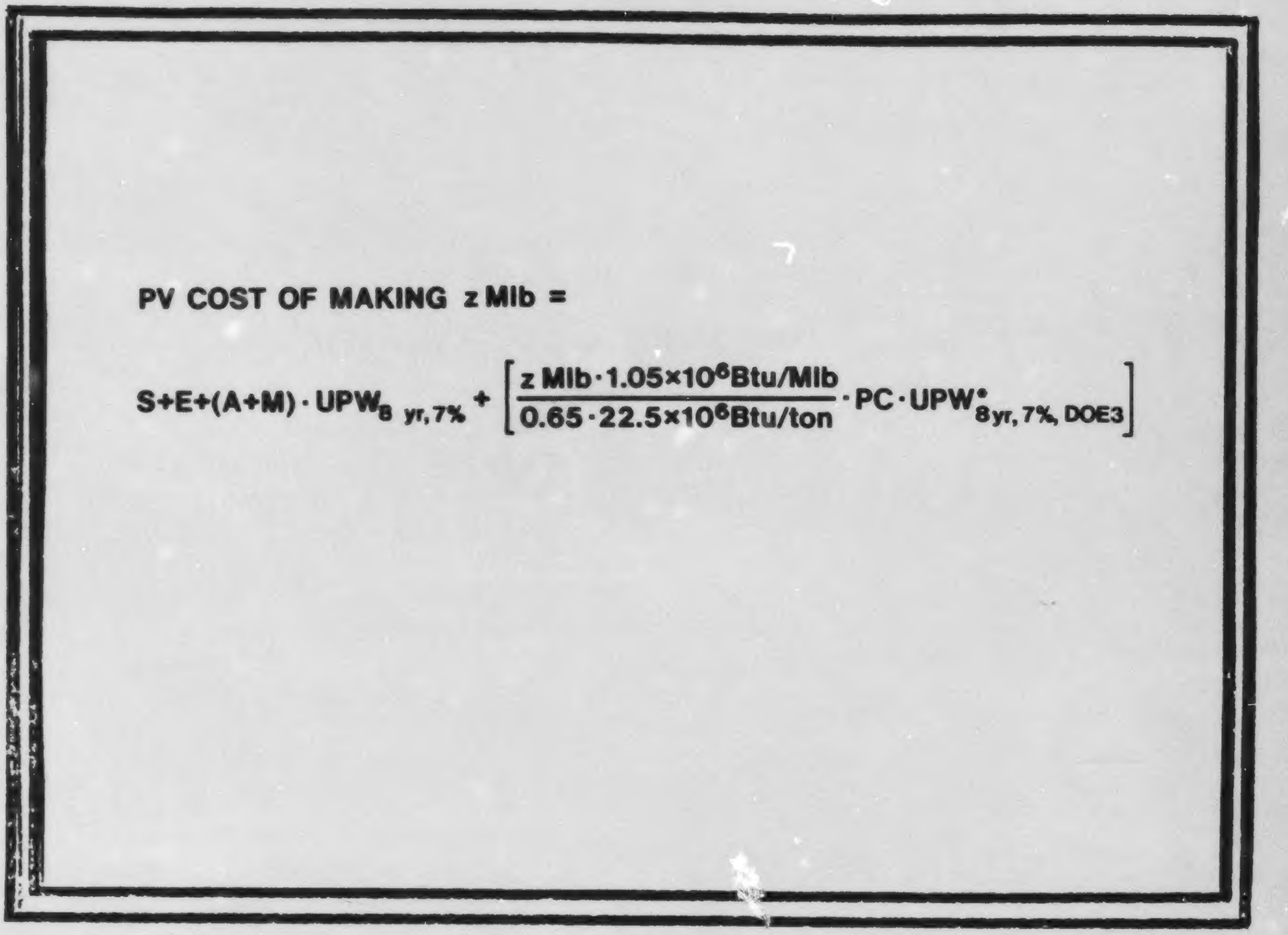
$$\text{PV COST OF BUYING z Mlb} = \text{PP} \cdot \text{z Mlb} \cdot \text{UPW}^{*}_{8\text{ yr},7\%,5\%}$$

$$= \$10.00 \cdot \text{z Mlb} \cdot \left(\frac{1+0.05}{0.07-0.05}\right)\left[1-\left(\frac{1+0.05}{1+0.07}\right)^{8}\right]$$

PV Cost of Buying zMlb

- Explain how the present value cost of buying the steam is calculated.

Slide 9



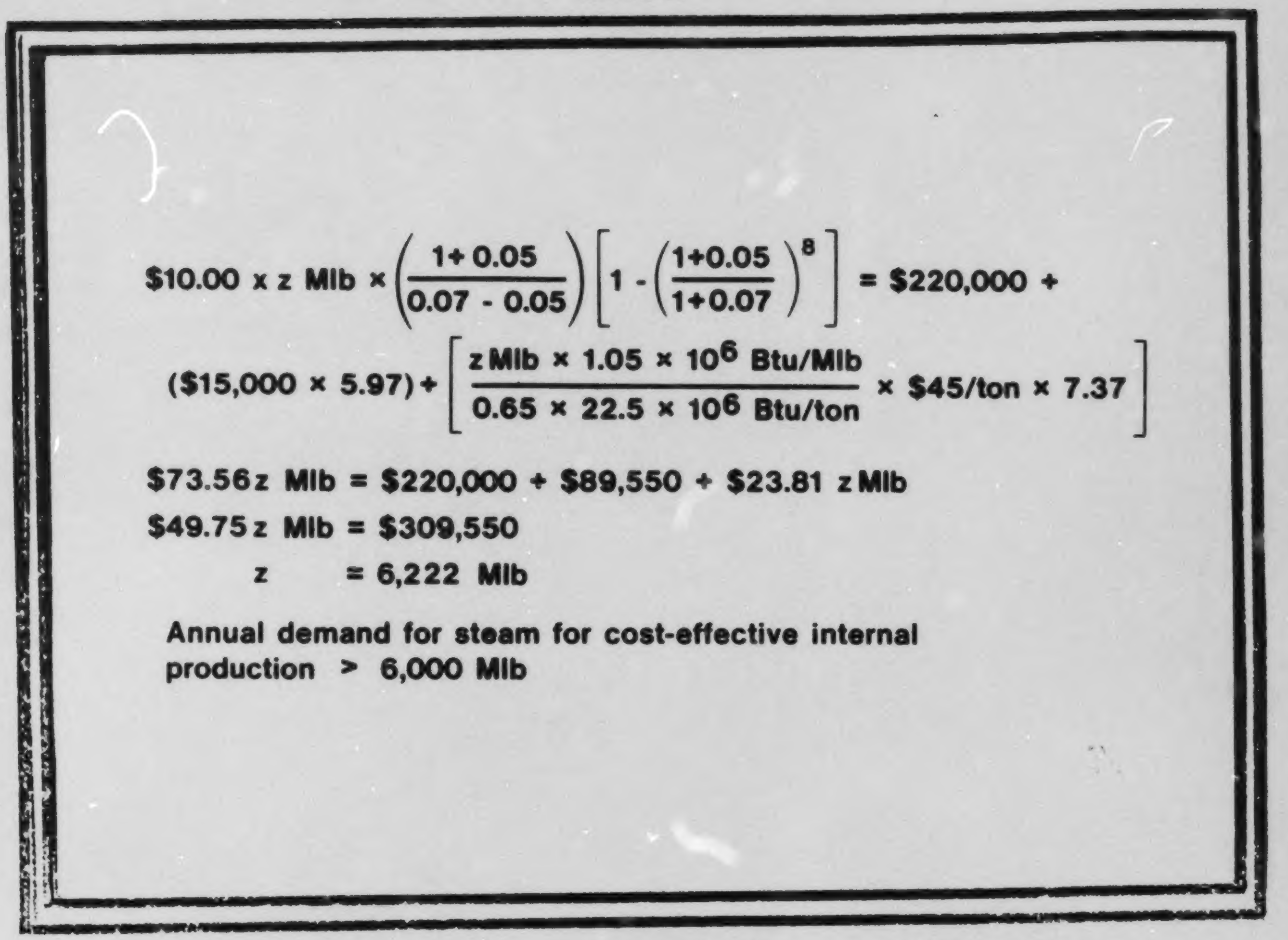
PV COST OF MAKING z Mlb =

$$S+E+(A+M)\cdot UPW_{8\ yr,7\%}+\left[\frac{z\ Mlb\cdot 1.05\times10^{6}Btu/Mlb}{0.65\cdot 22.5\times10^{6}Btu/ton}\cdot PC\cdot UPW^{*}_{8yr,7\%,\ DOE3}\right]$$

PV Cost of Making zMlb

- Explain how the present value cost of on-site generation of steam is calculated.

Slide 10



$$\$10.00 \times z \text{ Mlb} \times \left(\frac{1+0.05}{0.07-0.05}\right)\left[1-\left(\frac{1+0.05}{1+0.07}\right)^{8}\right] = \$220{,}000 +$$

$$(\$15{,}000 \times 5.97) + \left[\frac{z \text{ Mlb} \times 1.05 \times 10^{6} \text{ Btu/Mlb}}{0.65 \times 22.5 \times 10^{6} \text{ Btu/ton}} \times \$45/\text{ton} \times 7.37\right]$$

$$\$73.56 z \text{ Mlb} = \$220{,}000 + \$89{,}550 + \$23.81 z \text{ Mlb}$$

$$\$49.75 z \text{ Mlb} = \$309{,}550$$

$$z = 6{,}222 \text{ Mlb}$$

Annual demand for steam for cost-effective internal production > 6,000 Mlb

Annual Demand for Steam for Cost-Effective Internal Production

- Review problem solution.

Section 20

Team Problem: Break-Even Analysis

This problem gives participants experience in performing break-even analysis. Allow about five minutes for the class to read the problem. Discuss the problem. Ask the teams to solve the problem. Ask each team for its recommendation. Present and discuss the solution.

Team Problem: Break-Even Orders for a Computerized Procurement System

[Note: This hypothetical problem is intended only to illustrate the technique.]

Problem Statement:

A Federal agency procurement office is considering the purchase of a new computerized system that is expected to cut average labor time per order in half. The number of orders has been identified as a key determinant of the cost effectiveness of the system, and management wishes to make the decision based on cost effectiveness.

Past trends in procurement orders have been analyzed, and a projection has been made of future orders in terms of lower and upper boundary estimates. Over the next three years, the average projected low estimate is 500 orders per year and the average high is 800. Other data and assumptions are given below:

Data and Assumptions:

System purchase and installation cost = $45,000

Annual maintenance cost = $2,000
(Fixed by contract in constant dollars)

Service charge per order = $1.00
(Fixed by contract in constant dollars)

System life = 10 years

Salvage = 0

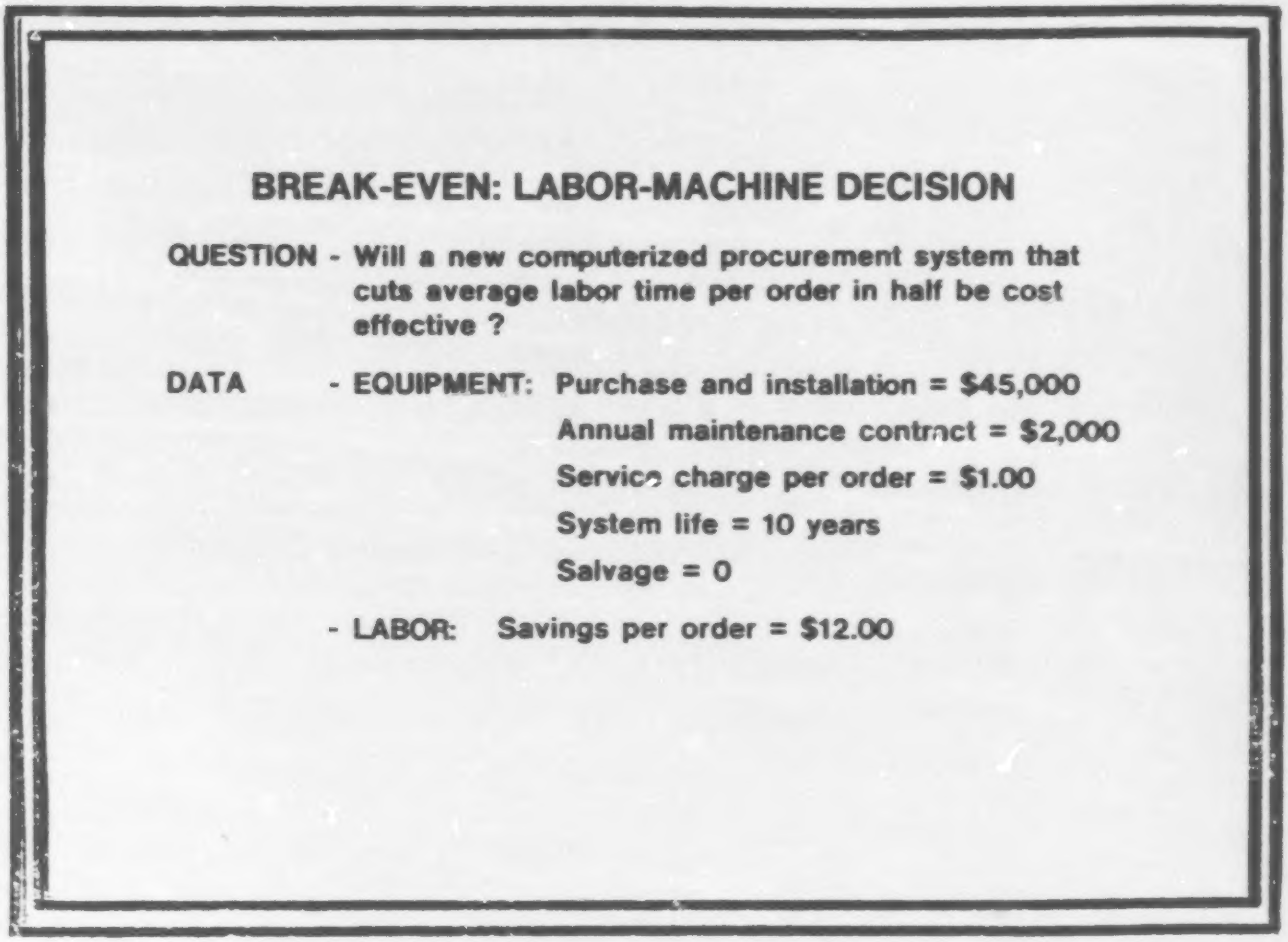
Labor savings per order = $12.00
(Constant dollars)

To Do:

Based on the data and assumptions, perform a break-even analysis of the annual procurement orders and, on this basis, advise management on the decision.

[Note: Assume the project is not regarded as an energy conservation project.]

Slide 1



BREAK-EVEN: LABOR-MACHINE DECISION

QUESTION - Will a new computerized procurement system that cuts average labor time per order in half be cost effective ?

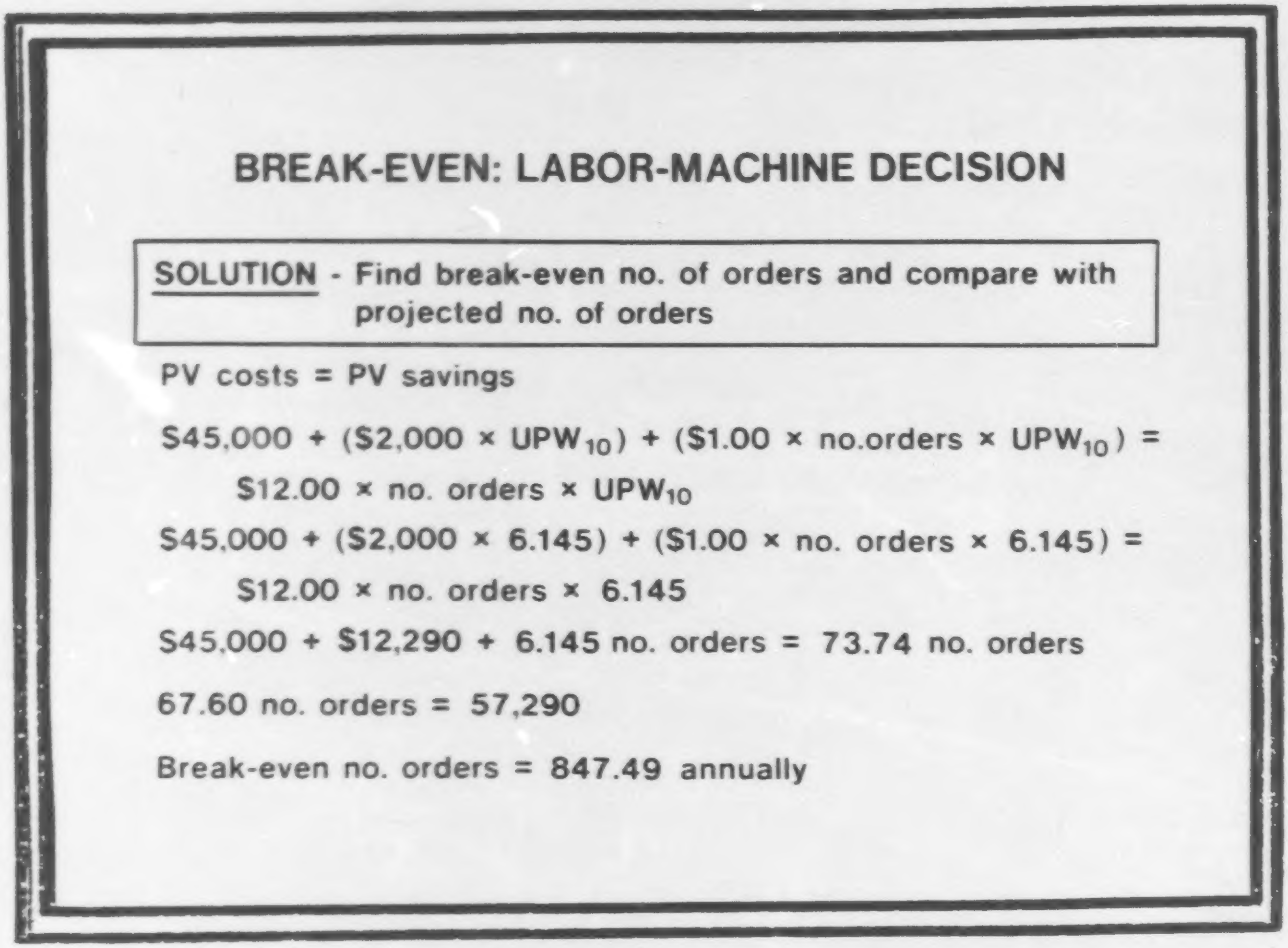
DATA - EQUIPMENT: Purchase and installation = $45,000
Annual maintenance contract = $2,000
Service charge per order = $1.00
System life = 10 years
Salvage = 0

- LABOR: Savings per order = $12.00

Break-Even: Labor-Machine Decision

- o Present the problem.

Slide 2



BREAK-EVEN: LABOR-MACHINE DECISION

SOLUTION - Find break-even no. of orders and compare with projected no. of orders

PV costs = PV savings

$\$45{,}000 + (\$2{,}000 \times UPW_{10}) + (\$1.00 \times \text{no.orders} \times UPW_{10}) =$
$\quad \$12.00 \times \text{no. orders} \times UPW_{10}$

$\$45{,}000 + (\$2{,}000 \times 6.145) + (\$1.00 \times \text{no. orders} \times 6.145) =$
$\quad \$12.00 \times \text{no. orders} \times 6.145$

$\$45{,}000 + \$12{,}290 + 6.145 \text{ no. orders} = 73.74 \text{ no. orders}$

$67.60 \text{ no. orders} = 57{,}290$

Break-even no. orders = 847.49 annually

Break-Even: Labor-Machine Decision

- Review problem solution.

Section 21

Computer Room Waste Heat Recovery Problem (70 Minutes)

This problem gives workshop participants the experience of calculating the net savings and the SIR for an energy conserving retrofit of an existing building. It is slightly more complex than previous problems in that calculations of Btu's saved and their conversion to pounds of steam are required for making the economic analyses. A break-even measure of the purchase and installation price of the heat exchanger is also computed. Since first costs of retrofits are not always certain, a range of first costs is used throughout the problem so that answers are bracketed. Project impacts are measured in terms of the absolute and percentage reductions in Btu consumption, both at the boundary for steam, and at the source for coal. Thus, this problem treats side issues that often arise in addition to the traditional cost effectiveness measures.

Allow approximately five minutes for the class to read the problem. Then explain the objectives of the problem as described above. Elaborate on the equation that calculates Btu's and converts them to pounds of steam provided in statement nine under Data and Assumptions. Ask for and answer questions about the problem.

Ask the class to proceed through the worksheets. Intervene after an appropriate work time between each worksheet to explain how the blanks were filled in.

Conclude the problem with a brief summary and a question and answer session.

Computer Room Waste Heat Recovery Problem

[Note: This is a hypothetical example intended only to illustrate the evaluation technique.]

Problem Statement: Would you recommend the following retrofit project for a Federal office building in Washington, D.C. (DOE Region 3)? The proposed project is to install a heat exchanger (with necessary piping and valves) for recovery of heat from waste condenser water from a computer room chiller for the purpose of preheating domestic hot water for the building.

Data and Assumptions:

(1) Condenser water at 95°F is currently delivered from the computer room water chiller to the cooling tower for dissipation of the thermal energy to the atmosphere.

(2) Purchased steam at $9.00 per thousand lbs (Mlb) is currently used to heat domestic hot water for the office building. The energy content of the steam is 1.05×10^6Btu/Mlb. The supplier of the steam uses coal to generate the steam with a plant efficiency of 65%.

(3) Domestic hot water consumption averages 1 gallon per person per day (GPD). The building is occupied 252 days per year and daily occupancy averages 3,000 people (P). The water intake temperature averages 60°F and the supply temperature is 120°F.

(4) Passing the 60°F domestic water supply through a heat exchanger through which the 95°F waste condenser water is routed will preheat it to 80°F.

(5) The installed cost of the heat exchanger (including all piping, insulation and valves) is estimated at between $6,000 and $7,000, depending on potential problems that may be encountered in installation.

(6) Maintenance cost on the heat recovery system is estimated at $200 per year in constant dollars.

(7) A replacement cost of $500 (constant dollars) for retubing the heat exchanger is expected at the end of 15 years.

(8) With proper maintenance and periodic replacements, the system is expected to last at least 25 years.

Note: Annual Energy Consumption (Mlbs. of steam) = [GPD x P x Dy/Yr x 8.34 lb/G x ΔT] ÷ 1.05 x 10^6Btu/Mlb.

Determine:

(A) Net present value savings.

(B) SIR for ranking this project relative to other projects.

(C) The break-even purchase and installation price of the heat exchanger.

Computer Room Waste Heat Recovery Problem

Remarks to Help the Class

Slide Number   Slide Title

3   Energy Costs Without the Retrofit

Note that steam is the energy type. Explain step-by-step how the annual quantity is calculated.

The UPW* factor is for coal, because coal is the fuel used to generate steam, and escalations in coal prices are assumed to be passed on through escalation in steam prices.

The annual quantity of energy consumption is computed by multiplying the number of pounds of water required by the number of degrees the water is to be raised and then dividing the product by the conversion factor to yield an answer in thousands (M) of pounds.

$$\frac{1\ \text{GPD} \times 3000\ \text{P} \times 252\ \text{Dy/Yr} \times 8.34\ \text{lb/G} \times (120^\circ - 60^\circ)}{1.05 \times 10^6\ \text{Btu/Mlb}} = 360.3\text{Mlb/Yr}$$

8   Energy Costs With Retrofit

The annual quantity is computed with the same formula as used in slide 3, but with a temperature increase from 80°F to 120°F instead of 60°F to 120°F.

9   Investment Costs with Retrofit

Actual costs are bracketed, and therefore subsequent calculations involving actual costs will be bracketed.

Computer Room Waste Heat Recovery Problem (Cont.)

Remarks to Help the Class

Slide Number	Slide Title
10	Annual Nonfuel O&M Costs With Retrofit The UPW factor, from page 115 of Handbook 135, for N=25, is 11.65. Note that the UPW factor and not the UPW* factor is used because the annual amount is fixed.
11	Nonannual O&M, Replacement, and Salvage With Retrofit The SPW factor, from page 114 of Handbook 135, for N=15, is .36.
14	Direct Calculation of Energy Savings The Handbook 135 worksheets are designed to accommodate a diversity of project analyses and are offered mainly as an aid to organizing the material. For many problems, however, it may be faster to go directly to differences between alternatives rather than compute the TLCC of each and then find the difference. The difference approach is illustrated in this slide. It shows a shortcut method to arriving at net savings of the retrofit. Since the heat exchanger raises the input water temperature 20°F, it saves the energy required to raise the required water by 20°F. These dollar energy savings ($17,218) can be calculated directly with the first formula. Subtracting all costs associated with the heat exchanger yields a net savings in the range $8,408 to $9,308.

Remarks to Help the Class

Slide Number	Slide Title
15	SIR

Explain that if the project ranking relative to other projects is unambiguous at this point (e.g., other SIR's are 1.5, 2.2, 5.0 and 10.0), then project ranking is not sensitive to the variation in investment cost estimated in this problem. However, in some cases, uncertainty about some aspect of a project might be cause to seek further information. For example, if the SIR's based on the estimated low and high ends of the cost range were, say 2.0 and 10.0, while competing projects had SIR's within this range, further information would be needed to rank the project in question relative to competing projects.

Slide Number	Slide Title
16	Break-Even Purchase & Installation Cost

The P_{BE} is the amount one can afford to pay for the heat exchanger and just break even on savings. The break-even cost in terms of what one could afford to pay (P_{BE}) equals $14,708.

Slide 1

COMPUTER ROOM
WASTE HEAT RECOVERY PROBLEM

Solution

Slide 2

IDENTIFYING INFORMATION

BUILDING:

LOCATION	Washington, D.C.
DOE REGION	3
USE	Office Building
TYPE	Commercial
LIFE	Indefinite

PROJECT Recovery of waste heat from computer room chiller to preheat domestic hot water

PROJECT LIFE 25 years

STUDY LIFE 25 years

Slide 3

A. ENERGY COSTS WITHOUT RETROFIT

TYPE	ANNUAL QUANTITY	UNIT PRICE	COST/ YEAR	UPW*	PV COSTS
STEAM	360.3 M lbs.	$9.00/M lbs.	3243	15.93	51,654
TOTAL					51,654

$$\left[\, 1 \text{ GPD} \times 3000 \text{ P} \times 252 \text{ Dy/yr} \times 8.34 \text{ lb/G} \times (120\text{-}60) \,\right] \div$$

$$1.05 \times 10^6 \text{ Btu/M lb} = 360.3 \text{ M lbs}$$

Slide 4

E. TLCC WITHOUT RETROFIT

1. PV ENERGY	51,654
2. PV INVESTMENT	
3. PV ANNUAL O&M	
4. PV NONANNUAL O&M	
5. PV REPLACEMENT	
6. PV SALVAGE	
7. TLCC	51,654

Slide 5

F. ENERGY COSTS WITH RETROFIT

TYPE	ANNUAL QUANTITY	UNIT PRICE	COST/ YEAR	UPW *	PV COSTS
STEAM	240.2 M lbs	9.00	2162	15.93	34,436
TOTAL					34,436

[1 GPD × 3000 P × 252 Dy/yr × 8.34 lb/G × (120-80)] ÷

1.05 × 10^6 Btu/M lb = 240.2 M lbs

Slide 6

G. INVESTMENT COSTS WITH RETROFIT

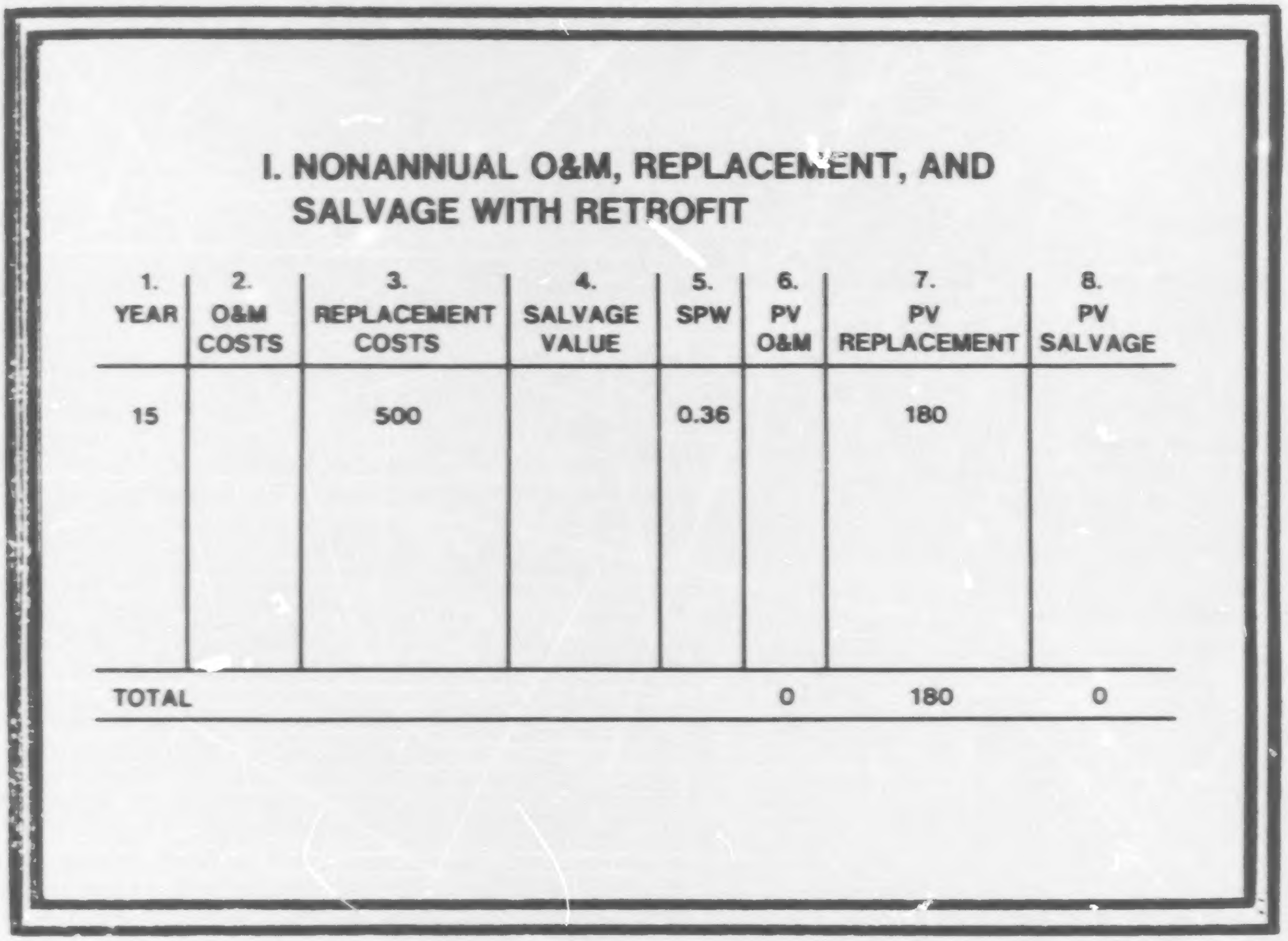
1. ACTUAL COSTS	6,000 - 7,000
2. ADJUSTMENT FACTOR	0.9
3. ADJUSTED COSTS	5,400 - 6,300
4. RENOVATION COSTS	0
5. ADJUSTED PV	5,400 - 6,300

Slide 7

H. ANNUAL NONFUEL O&M COSTS WITH RETROFIT

1. AMOUNT	2. UPW	3. PV COSTS
200	11.65	2,330

Slide 8



I. NONANNUAL O&M, REPLACEMENT, AND SALVAGE WITH RETROFIT

1. YEAR	2. O&M COSTS	3. REPLACEMENT COSTS	4. SALVAGE VALUE	5. SPW	6. PV O&M	7. PV REPLACEMENT	8. PV SALVAGE
15		500		0.36		180	
TOTAL					0	180	0

Slide 9

J. TLCC WITH RETROFIT

1. PV ENERGY	34,436
2. PV ADJUSTED INVESTMENT	5,400 - 6,300
3. PV ANNUAL O&M	2,330
4. PV NONANNUAL O &M	0
5. PV REPLACEMENT	180
6. PV SALVAGE	0
7. TLCC	42,346 - 43,246

Slide 10

K. NET SAVINGS OF PROJECT

1. TLCC WITHOUT	51, 654
2. TLCC WITH	42,346 - 43,246
3. NET SAVINGS	8,408 - 9,308

Slide 11

ALTERNATIVE TO LCC WITH & WITHOUT RETROFIT: DIRECT CALCULATION OF ENERGY SAVINGS

$$\left(\left[\text{GPD} \times 3{,}000\text{P} \times 252\ \text{Dy/yr} \times 8.34\ \text{lb/G} \times \underbrace{(80\text{-}60)}_{\Delta\text{T of retrofit}}\right] \div 1.05 \times 10^{6}\ \text{Btu/M lb}\right) \times \$9.00 \times 15.93 = \$17{,}218$$

Subtract costs:

17,218 - (5,400 → 6,300) - 2,330 - 180 = 8,408 → 9,308

i.e., Net savings = Savings - Costs = $\text{TLCC}_{\text{without retrofit}} - \text{TLCC}_{\text{with retrofit}}$

Slide 12

L. SIR

1. NUMERATOR	
a. Δ ENERGY COST	(51,654-34,436)= 17,218
b. Δ NONFUEL O&M	-2,330
c. NUMERATOR	14,888
2. DENOMINATOR	
a. INVESTMENT	5,400 - 6,300
b. REPLACEMENT	180
c. SALVAGE	0
d. DENOMINATOR	5,580 - 6,480
3. SIR	2.30 - 2.67

Slide 13

BREAK-EVEN
PURCHASE & INSTALLATION COST (P_{BE})

Costs = Savings

$P_{BE} + (O\&M) + R = E$

$P_{BE} = \$17,218 - \$2,330 - \$180$

$P_{BE} = \$14,708$

Section 22

Slide Presentation: Replacement, Retirement, and Obsolescence

This session is based on the material provided in the Workbook section on replacement. Discuss the objective, distinguish the various concepts of life, and present the problem illustrations.

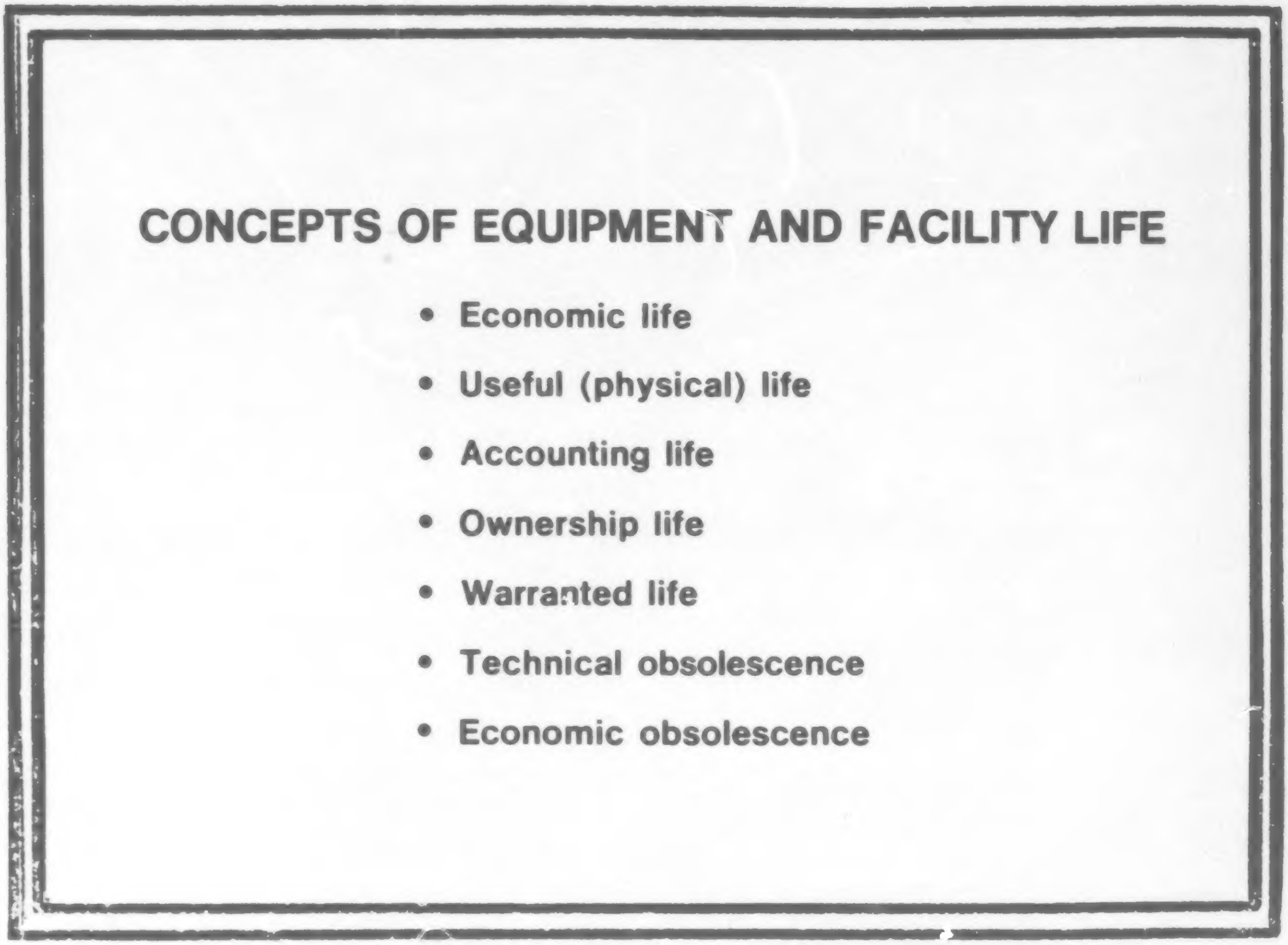
Slide 1

Replacement, Retirement,
and
Obsolescence

Replacement, Retirement, and Obsolescence

- Present the introduction.

Slide 2



CONCEPTS OF EQUIPMENT AND FACILITY LIFE

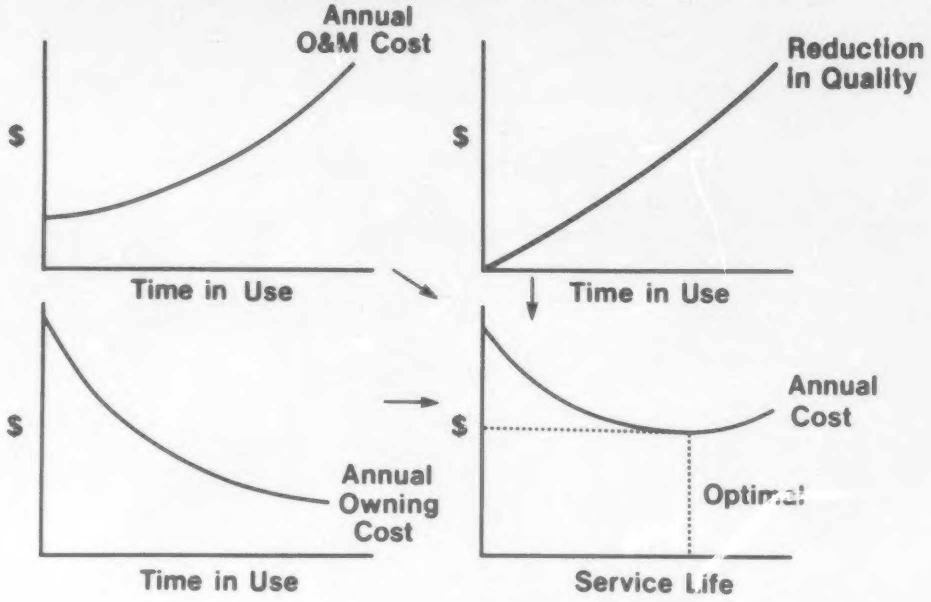
- Economic life
- Useful (physical) life
- Accounting life
- Ownership life
- Warranted life
- Technical obsolescence
- Economic obsolescence

Concepts of Equipment and Facility Life

o Discuss the different concepts of life and explain that the topic of this session is "economic life" and the related concept "economic obsolescence."

Slide 3

ESTIMATING ECONOMIC LIFE ≡ DETERMINING OPTIMAL REPLACEMENT POLICY



Estimating Economic Life = Determining Optimal Replacement Policy

- Explain that estimating the economic life is synonymous with determining the optimal replacement policy.
- Discuss each component of cost shown in the first three graphs and explain the influence of each on optimal replacement.
- Discuss the fourth graph which sums the costs of the first three graphs, pointing out the implication of the shape of the curve.

Illustrative Problem: Determining Optimal Replacement of Like Equipment

[Note: This hypothetical example is intended only to illustrate the technique.]

Question: How frequently should a given piece of equipment (E_A) be replaced?

Data and Assumptions:

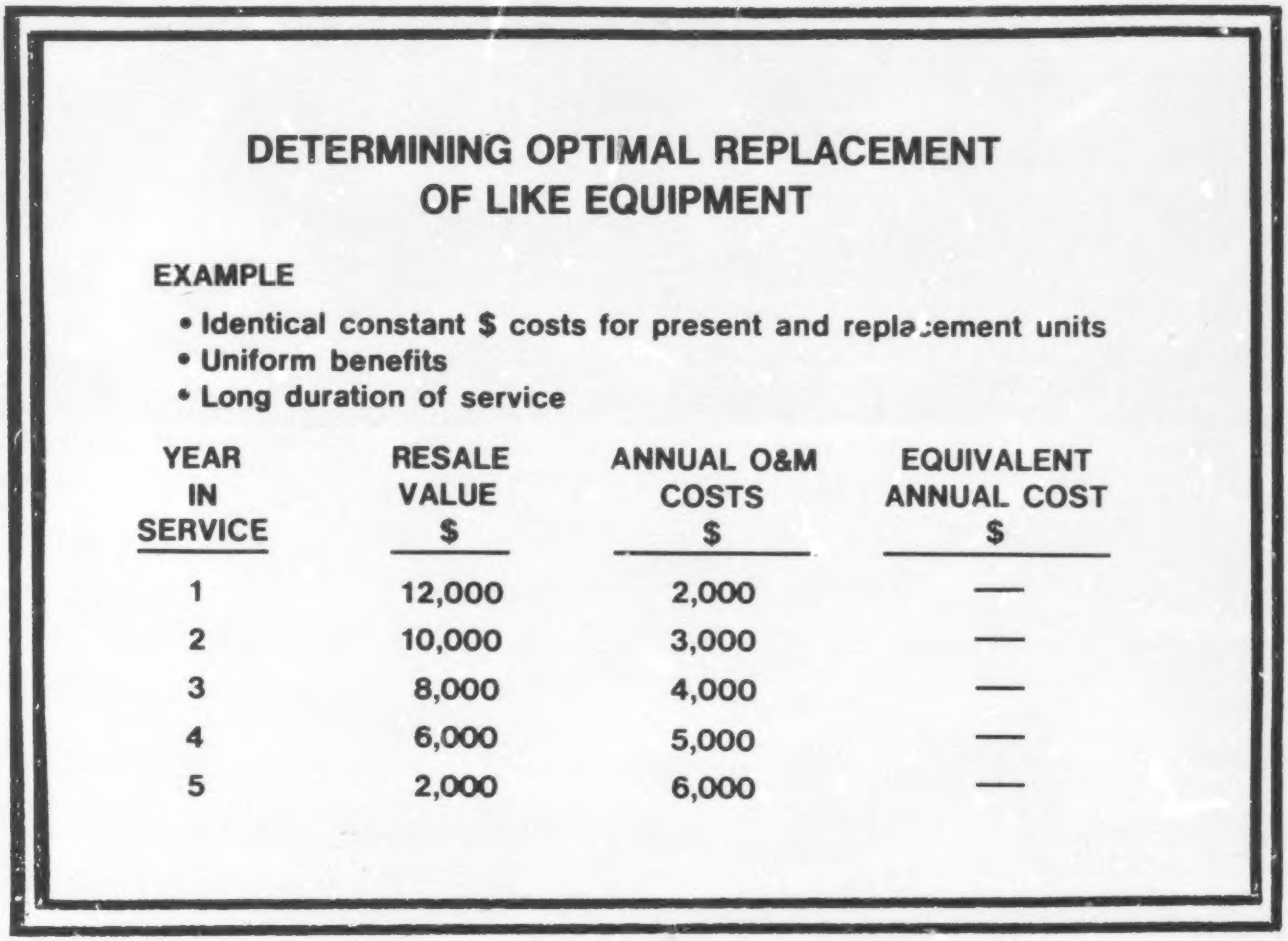
- o Identical constant dollar costs (C) for present and future replacement units of E_A of $20,000
- o Uniform benefits
- o Long duration of service
- o The following resale values (S) and operation, maintenance, and repair costs (O+M+R) for each year the equipment is in service:

Year in Service	Resale Value (constant $)	O&M Cost (constant $)
1	12,000	2,000
2	10,000	3,000
3	8,000	4,000
4	6,000	5,000
5	2,000	6,000

Approach: Find the number of years until replacement (n) for which the annualized cost (AC(n)) is minimum, where

$$AC(n) = [C - (S(n) \times SPW(n)) + \sum_{j=1}^{n} [(O+M+R)_j \times SPW_j]] \times UCR(n)$$

Slide 4



DETERMINING OPTIMAL REPLACEMENT OF LIKE EQUIPMENT

EXAMPLE

- Identical constant $ costs for present and replacement units
- Uniform benefits
- Long duration of service

YEAR IN SERVICE	RESALE VALUE $	ANNUAL O&M COSTS $	EQUIVALENT ANNUAL COST $
1	12,000	2,000	—
2	10,000	3,000	—
3	8,000	4,000	—
4	6,000	5,000	—
5	2,000	6,000	—

Determining Optimal Replacement of Like Equipment

- Refer class to the illustrative replacement problem in section 9 of the seminar Workbook.
- Discuss the assumptions given in the Workbook, and explain the cost elements required to solve the problem.

Slide 5

CALCULATE EQUIVALENT ANNUAL COST FOR DIFFERENT REPLACEMENT TIMES

Calculate Equivalent Annual Cost for Different Replacement Times

- Discuss the solution approach and explain how the annual costs are calculated for alternative replacement times.

Slides 6-11

$$AC(n) = \left[C - \left(S(n) \times SPW(n) \right) + \sum_{j=1}^{n} \left[(O + M_j + R_j) \times SPW_j \right] \right] \left(UCR(n) \right)$$

$$AC(1) = \left[\left[\$20{,}000 - (12{,}000 \times 0.93) \right] + (2{,}000 \times 0.93) \right] (1.07) = \$11{,}449$$

$$AC(2) = \left[\left[\$20{,}000 - (10{,}000 \times 0.87) \right] + \left[(2{,}000 \times 0.93) + (3{,}000 \times 0.87) \right] \right] (0.553) = \$8{,}721$$

$$AC(3) = \left[\left[\$20{,}000 - (8{,}000 \times 0.82) \right] + \left[(2{,}000 \times 0.93) + (3{,}000 \times 0.87) + (4{,}000 \times 0.82) \right] \right] (0.381) = \$8{,}073$$

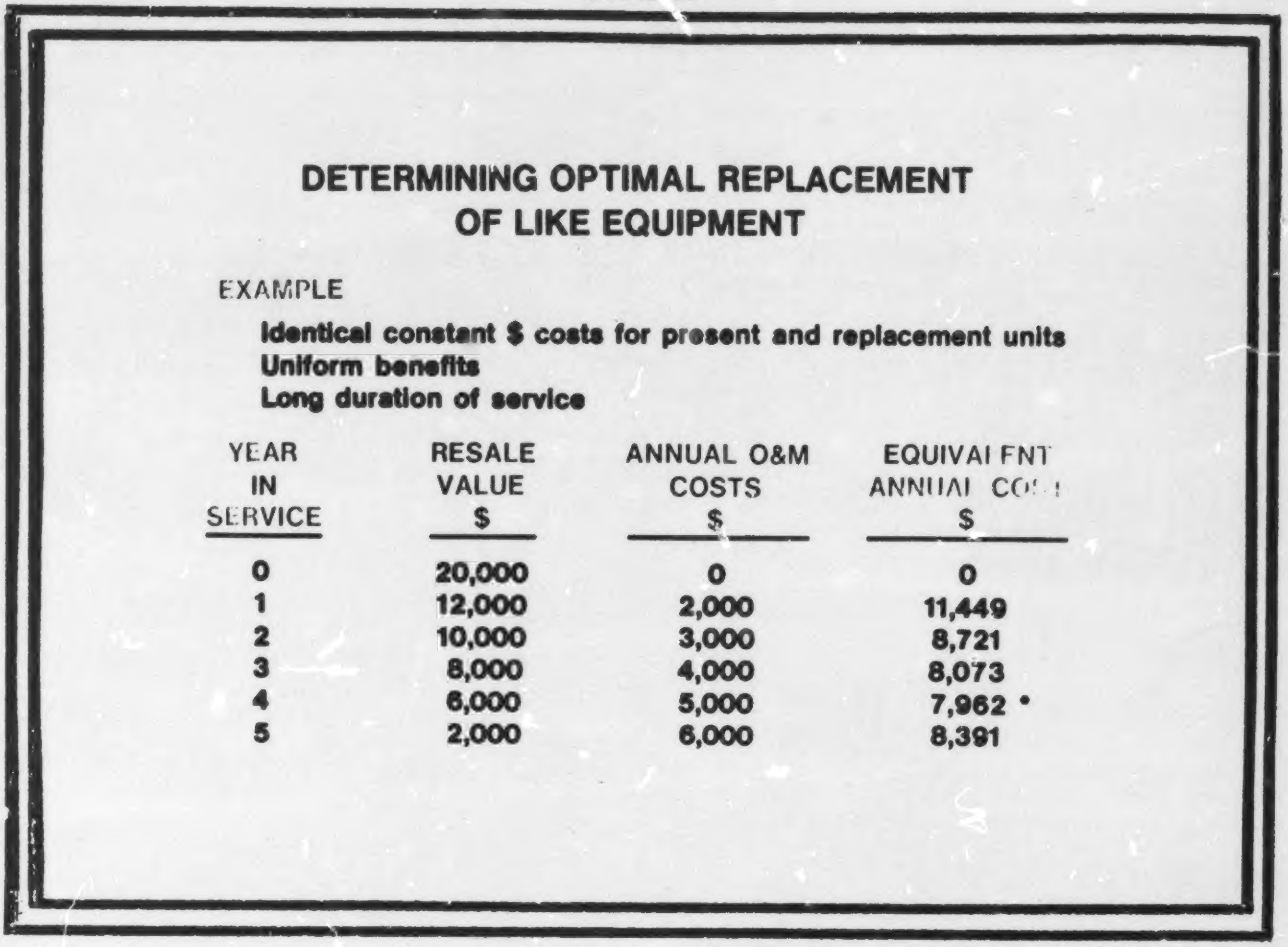
$$AC(4) = \left[\left[\$20{,}000 - (6{,}000 \times 0.76) \right] + \left[(2{,}000 \times 0.93) + (3{,}000 \times 0.87) + (4{,}000 \times 0.82) + (5{,}000 \times 0.76) \right] \right] (0.295) = \$7{,}962$$

$$AC(5) = \left[\left[\$20{,}000 - (2{,}000 \times 0.71) \right] + \left[(2{,}000 \times 0.93) + (3{,}000 \times 0.87) + (4{,}000 \times 0.82) + (5{,}000 \times 0.76) + (6{,}000 \times 0.71) \right] \right] (0.244) = \$8{,}391$$

AC(n), AC(i), AC(2), AC(3), AC(4), AC(5)

- Go through several of the calculations for different replacement times.

Slide 12



DETERMINING OPTIMAL REPLACEMENT OF LIKE EQUIPMENT

EXAMPLE

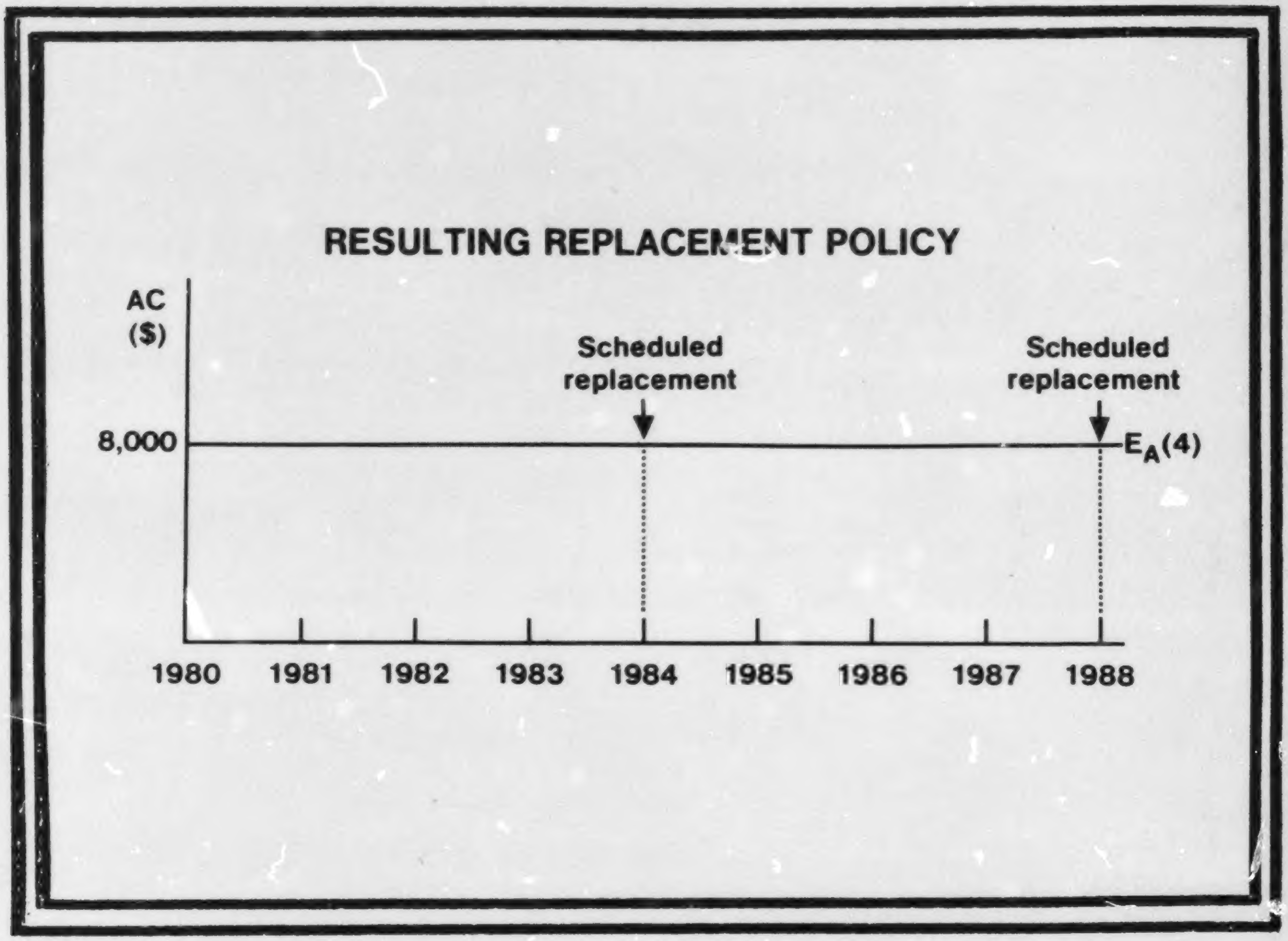
Identical constant $ costs for present and replacement units
Uniform benefits
Long duration of service

YEAR IN SERVICE	RESALE VALUE $	ANNUAL O&M COSTS $	EQUIVALENT ANNUAL COST $
0	20,000	0	0
1	12,000	2,000	11,449
2	10,000	3,000	8,721
3	8,000	4,000	8,073
4	6,000	5,000	7,962 •
5	2,000	6,000	8,391

Determining Optimal Replacement of Like Equipment

- Point out the optimal replacement time.

Slide 13

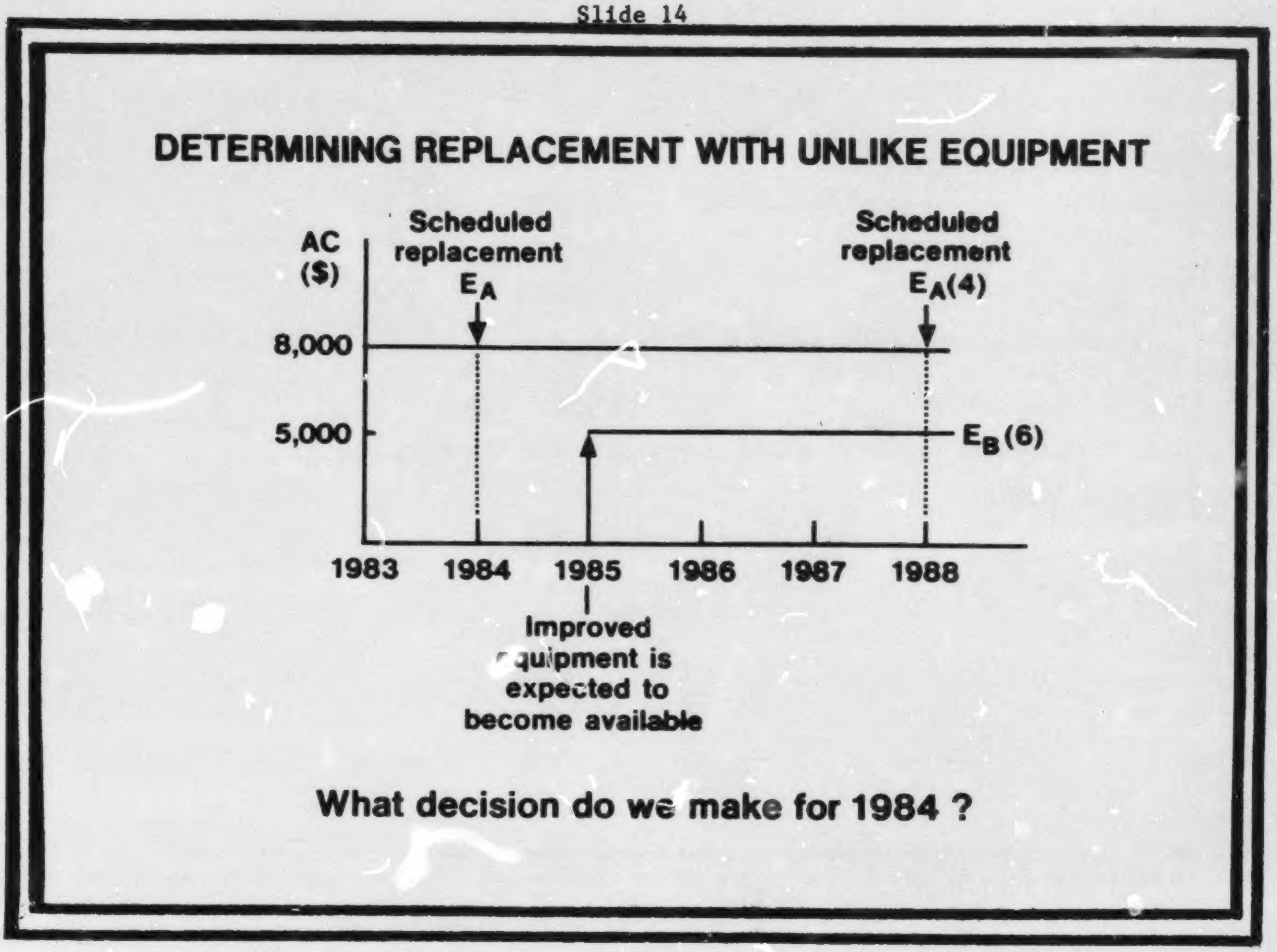


RESULTING REPLACEMENT POLICY

Resulting Replacement Policy

- Note that the preceding analysis supports the replacement schedule depicted in this slide.

Slide 14



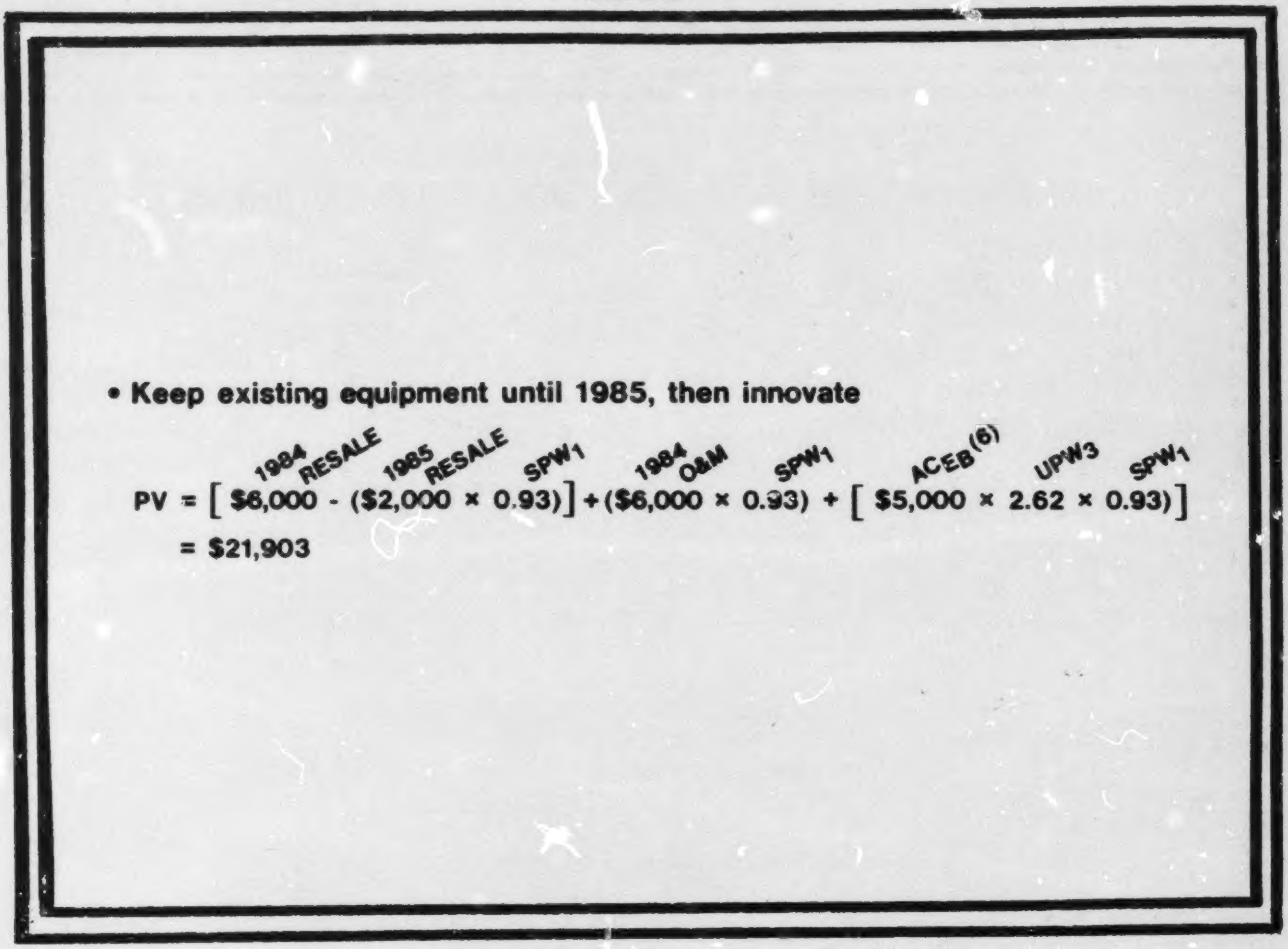
DETERMINING REPLACEMENT WITH UNLIKE EQUIPMENT

What decision do we make for 1984 ?

Determining Replacement with Unlike Equipment

- Introduce the new information presented in the Workbook illustrative problem.
- Ask what decision should be made in 1984.
- Ask for alternative decisions.
- List these alternatives on a flip chart.

Slide 15



- **Keep existing equipment until 1985, then innovate**

$$PV = \left[\overset{\text{1984 RESALE}}{\$6{,}000} - (\overset{\text{1985 RESALE}}{\$2{,}000} \times \overset{SPW_1}{0.93})\right] + (\overset{\text{1984 O\&M}}{\$6{,}000} \times \overset{SPW_1}{0.93}) + \left[\overset{ACEB^{(6)}}{\$5{,}000} \times \overset{UPW3}{2.62} \times \overset{SPW_1}{0.93})\right]$$

$$= \$21{,}903$$

Keep Existing Equipment Until 1985, Then Innovate

o Determine the present value cost of this alternative.

Slide 16

- **Replace in 1984 with E_A and innovate in 1985**

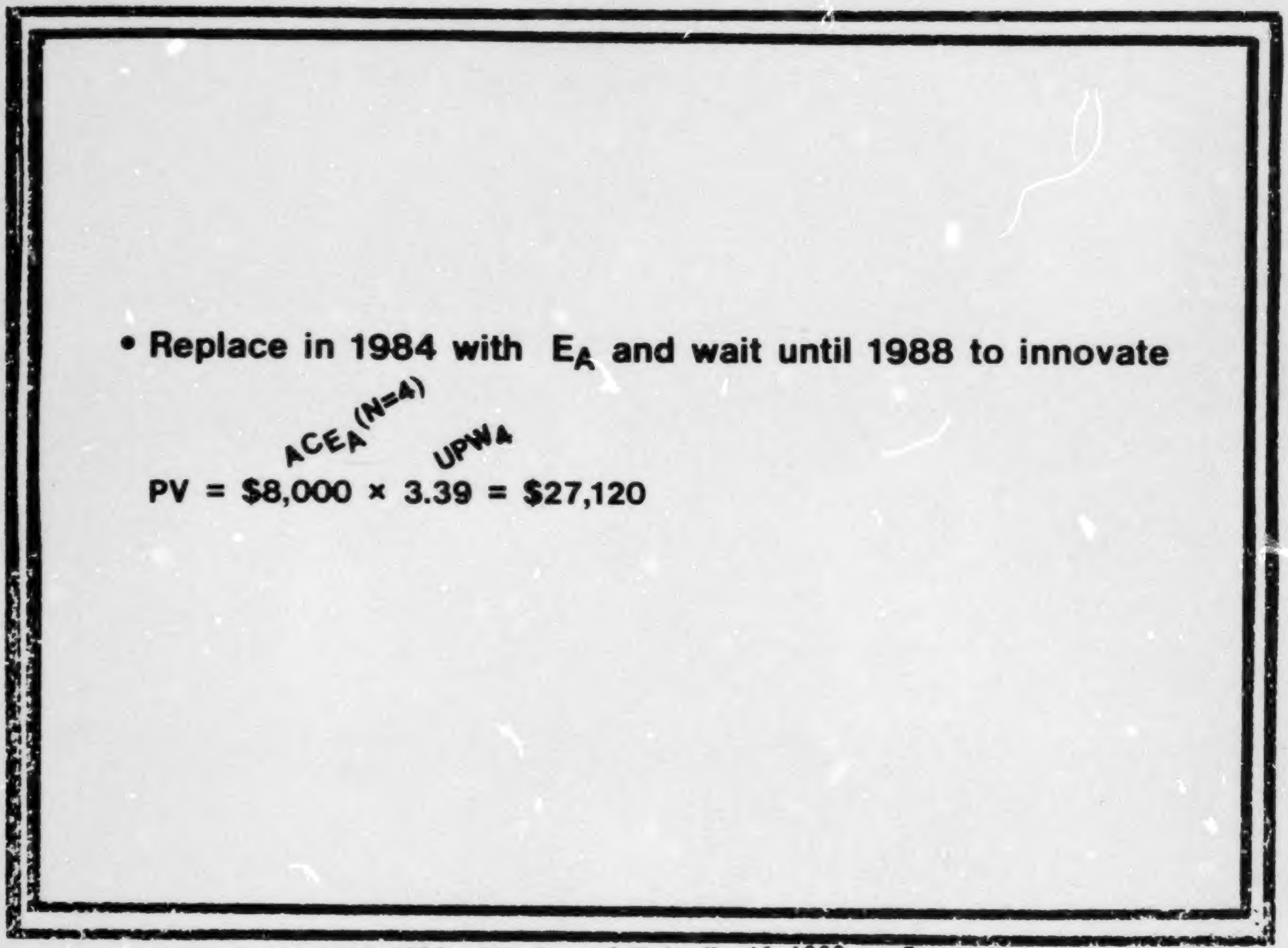
$$PV = \left[\overset{\text{FIRST COST}}{\$20{,}000} - (\overset{\text{RESALE(1)}}{\$12{,}000} \times \overset{SPW_1}{0.93})\right] + (\overset{\text{O\&M(1)}}{\$2{,}000} \times \overset{SPW_1}{0.93}) + (\overset{ACE_B\,(N=6)}{\$5{,}000} \times \overset{UPW_3}{2.62} \times \overset{SPW_1}{0.93})$$

$$= \$22{,}883$$

Replace in 1984 with E_A and Innovate in 1985

o Determine the present value cost of this alternative.

Slide 17



- **Replace in 1984 with E_A and wait until 1988 to innovate**

$$PV = \overset{ACE_A(N=4)}{\$8{,}000} \times \overset{UPW4}{3.39} = \$27{,}120$$

Replace in 1984 with E_A and Wait Until 1988 to Innovate

o Determine the present value cost of this alternative.

Section 23

Team Problem: Determining Optimal Retirement of Equipment

This session is intended to give participants experience in solving replacement problems. Allow the class about five minutes to read the problem. Discuss the problem. Ask the teams to solve the problem. Ask for the results. Review the solution.

Team Problem--Determining Optimal Retirement of Equipment

[Note: This hypothetical example is intended only to illustrate the technique.]

Problem Statement: The existing motor-generator sets which power passenger and freight elevators in a Federal building complex consume 2 million kWh's of electricity per year. At the time of the analysis (early 1983), electricity costs $0.06/kWh, and the price is projected to increase over the next 5 years at an annual compound rate 5 percent faster than general price inflation and thereafter at a rate 1 percent faster than the general inflation rate.

With an extensive overhaul and modifications costing $50,000, it is estimated that annual power consumption could be reduced by 15 percent and equipment life extended to as long as 25 years. Without the overhaul, the equipment is expected to last another 5 years, at which time overhaul will no longer be feasible.

New elevator power equipment is available at a purchase and installation cost of $400,000. It will cost $20,000 to remove and dispose of the old equipment and to prepare the machine rooms to receive the new equipment. There is no resale or reuse market for this kind of equipment when it is removed from service. The new equipment is expected to be 25 percent more energy efficient than the existing equipment without the overhaul. The new equipment is expected to last for the duration of the building life which is estimated to be indefinite.

No appreciable difference is estimated in maintenance and repair costs of the new and existing system, whether overhauled or not. The new equipment is expected to continue to be "state-of-the-art" for the foreseeable future, and its constant dollar costs are expected to remain the same over time.

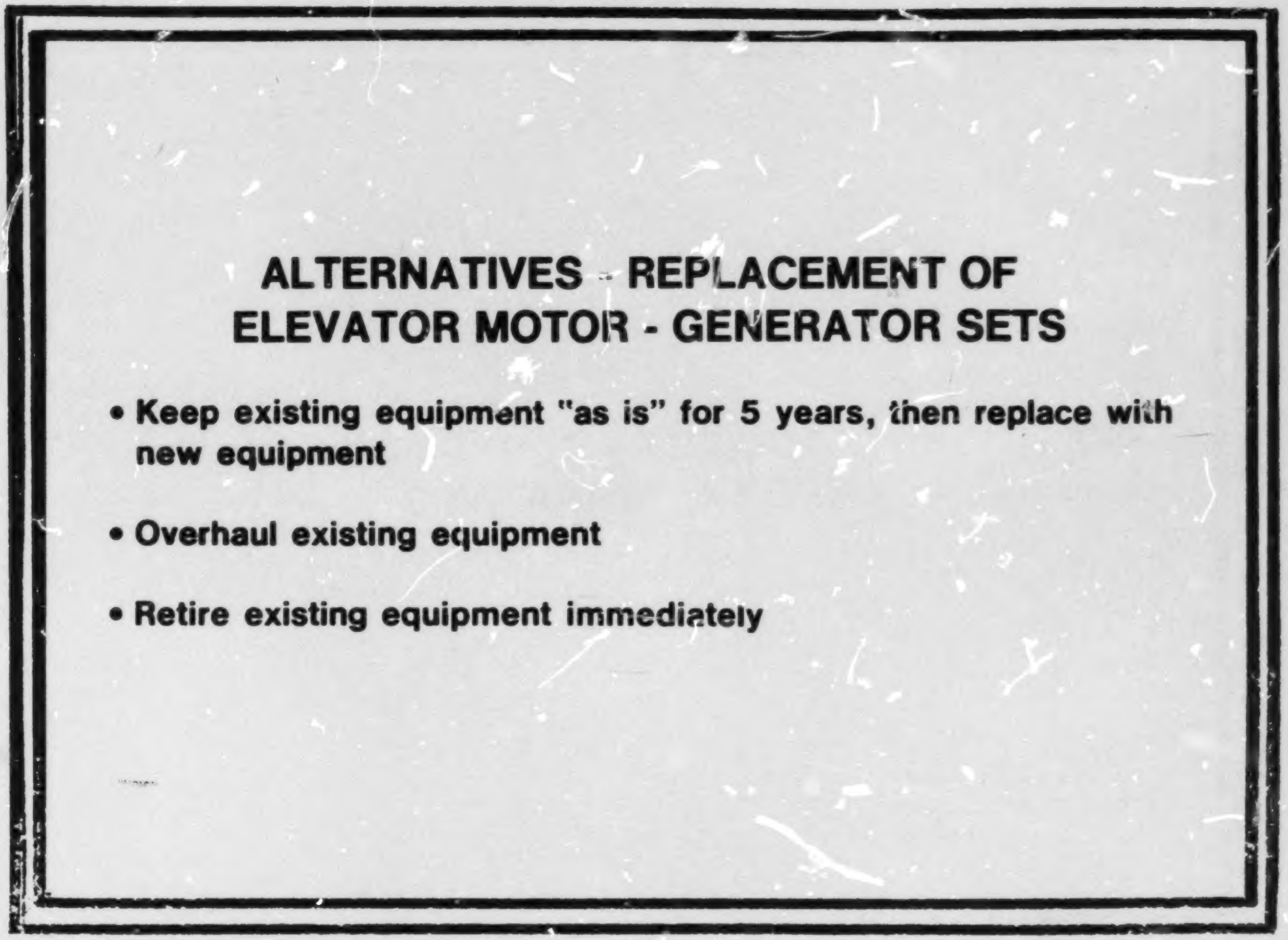
Determine:

(1) Decision alternatives to be considered.

(2) The estimated least-cost alternative.

(3) The net savings estimated to be derived from making the cost-effective decision.

Slide 1



ALTERNATIVES - REPLACEMENT OF ELEVATOR MOTOR - GENERATOR SETS

- Keep existing equipment "as is" for 5 years, then replace with new equipment
- Overhaul existing equipment
- Retire existing equipment immediately

Alternatives--Replacement of Elevator Motor-Generator Sets

o Discuss the alternatives.

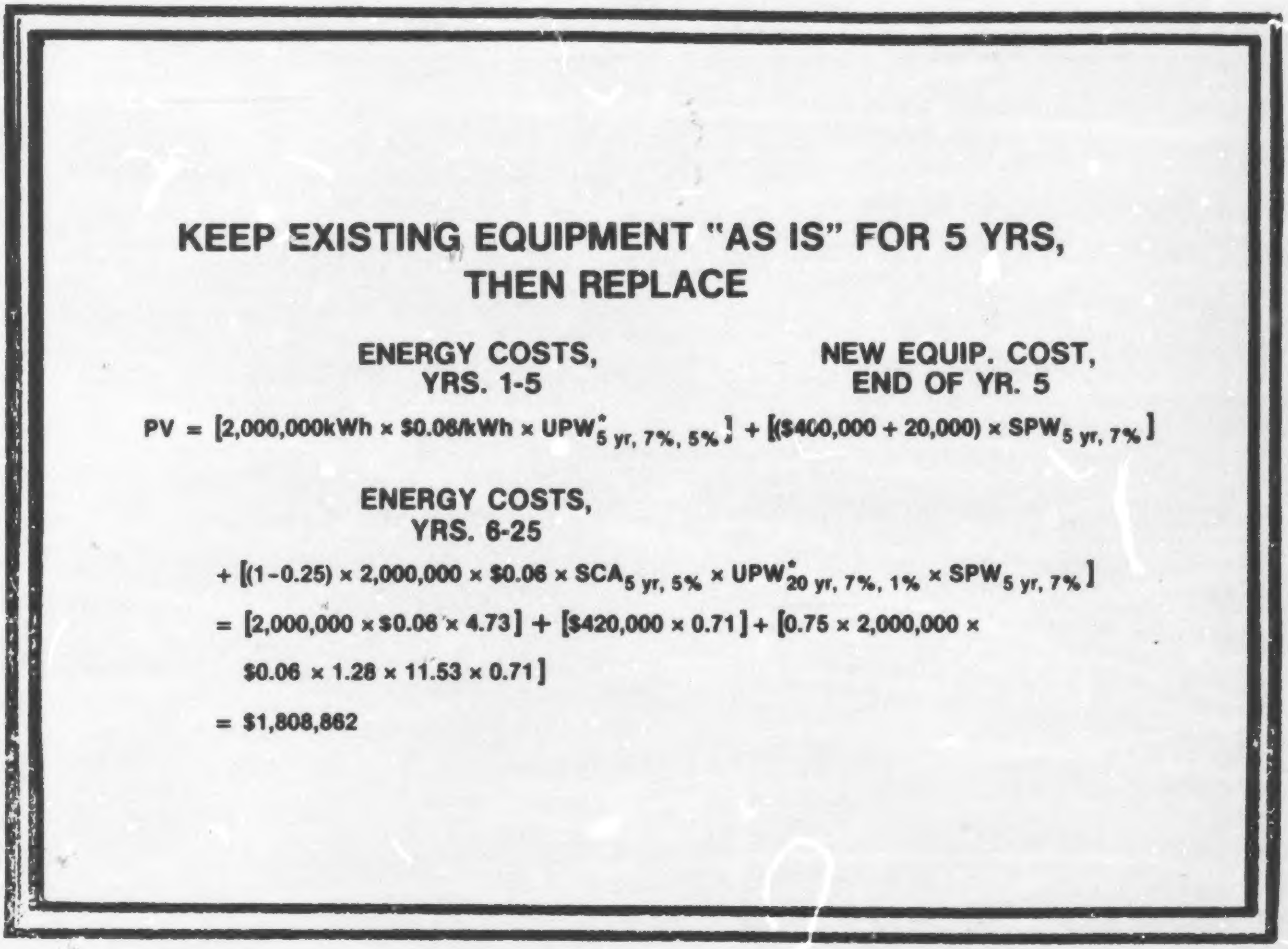
Slide 2

SOLUTION: COMPARE PV COSTS FOR 1984-1988 UNDER ALTERNATIVES

Solution: Compare PV Costs for 1984-1988 Under Alternatives

- o Explain approach for solving the problem.

Slide 3



KEEP EXISTING EQUIPMENT "AS IS" FOR 5 YRS, THEN REPLACE

ENERGY COSTS, YRS. 1-5 — **NEW EQUIP. COST, END OF YR. 5**

$$PV = \left[2{,}000{,}000\text{kWh} \times \$0.06/\text{kWh} \times UPW^{*}_{5\ yr,\ 7\%,\ 5\%}\right] + \left[(\$400{,}000 + 20{,}000) \times SPW_{5\ yr,\ 7\%}\right]$$

ENERGY COSTS, YRS. 6-25

$$+ \left[(1-0.25) \times 2{,}000{,}000 \times \$0.06 \times SCA_{5\ yr,\ 5\%} \times UPW^{*}_{20\ yr,\ 7\%,\ 1\%} \times SPW_{5\ yr,\ 7\%}\right]$$

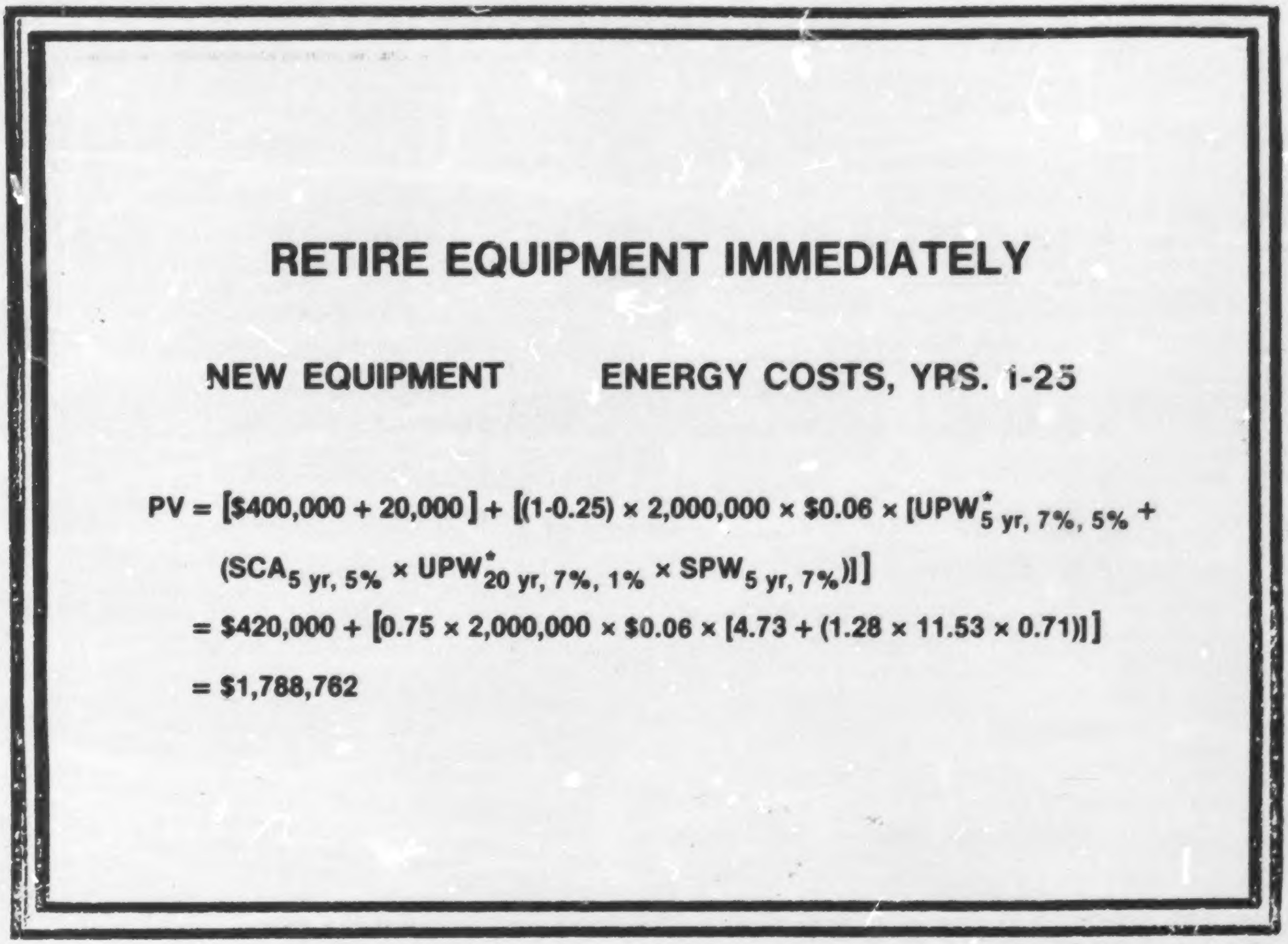
$$= \left[2{,}000{,}000 \times \$0.06 \times 4.73\right] + \left[\$420{,}000 \times 0.71\right] + \left[0.75 \times 2{,}000{,}000 \times \$0.06 \times 1.28 \times 11.53 \times 0.71\right]$$

$$= \$1{,}808{,}862$$

Keep Existing Equipment "As Is" for 5 Years, then Replace

- Show how the present value of this alternative is calculated.

Slide 4



RETIRE EQUIPMENT IMMEDIATELY

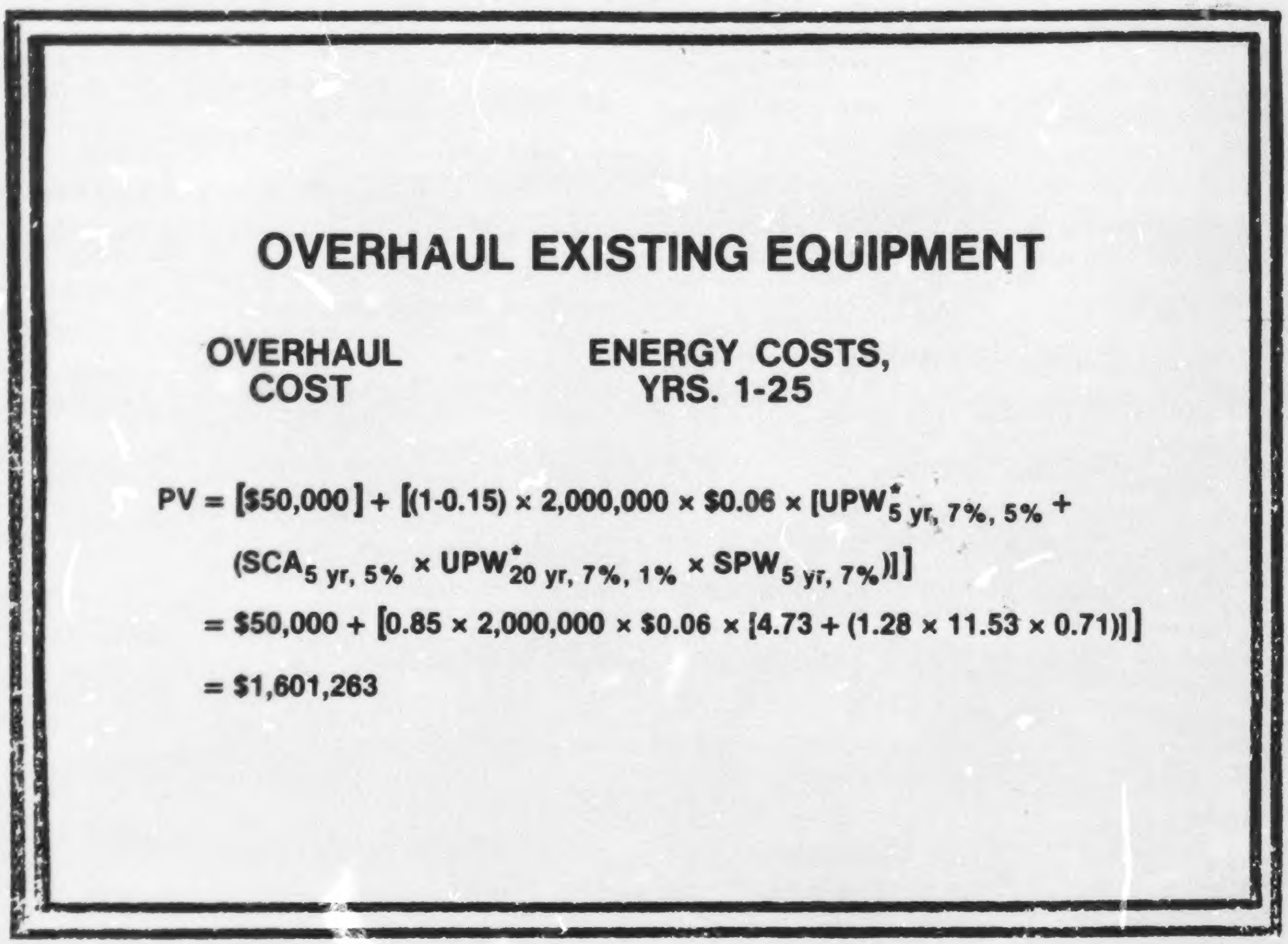
NEW EQUIPMENT **ENERGY COSTS, YRS. 1-25**

$$\begin{aligned} PV &= [\$400{,}000 + 20{,}000] + [(1-0.25) \times 2{,}000{,}000 \times \$0.06 \times [UPW^{*}_{5\text{ yr}, 7\%, 5\%} + \\ &\quad (SCA_{5\text{ yr}, 5\%} \times UPW^{*}_{20\text{ yr}, 7\%, 1\%} \times SPW_{5\text{ yr}, 7\%})]] \\ &= \$420{,}000 + [0.75 \times 2{,}000{,}000 \times \$0.06 \times [4.73 + (1.28 \times 11.53 \times 0.71)]] \\ &= \$1{,}788{,}762 \end{aligned}$$

Retire Equipment Immediately

- Show how the present value of this alternative is calculated.

Slide 5



OVERHAUL EXISTING EQUIPMENT

OVERHAUL COST **ENERGY COSTS, YRS. 1-25**

$$PV = [\$50{,}000] + [(1-0.15) \times 2{,}000{,}000 \times \$0.06 \times [UPW^{*}_{5\text{ yr},\,7\%,\,5\%} + (SCA_{5\text{ yr},\,5\%} \times UPW^{*}_{20\text{ yr},\,7\%,\,1\%} \times SPW_{5\text{ yr},\,7\%})]]$$

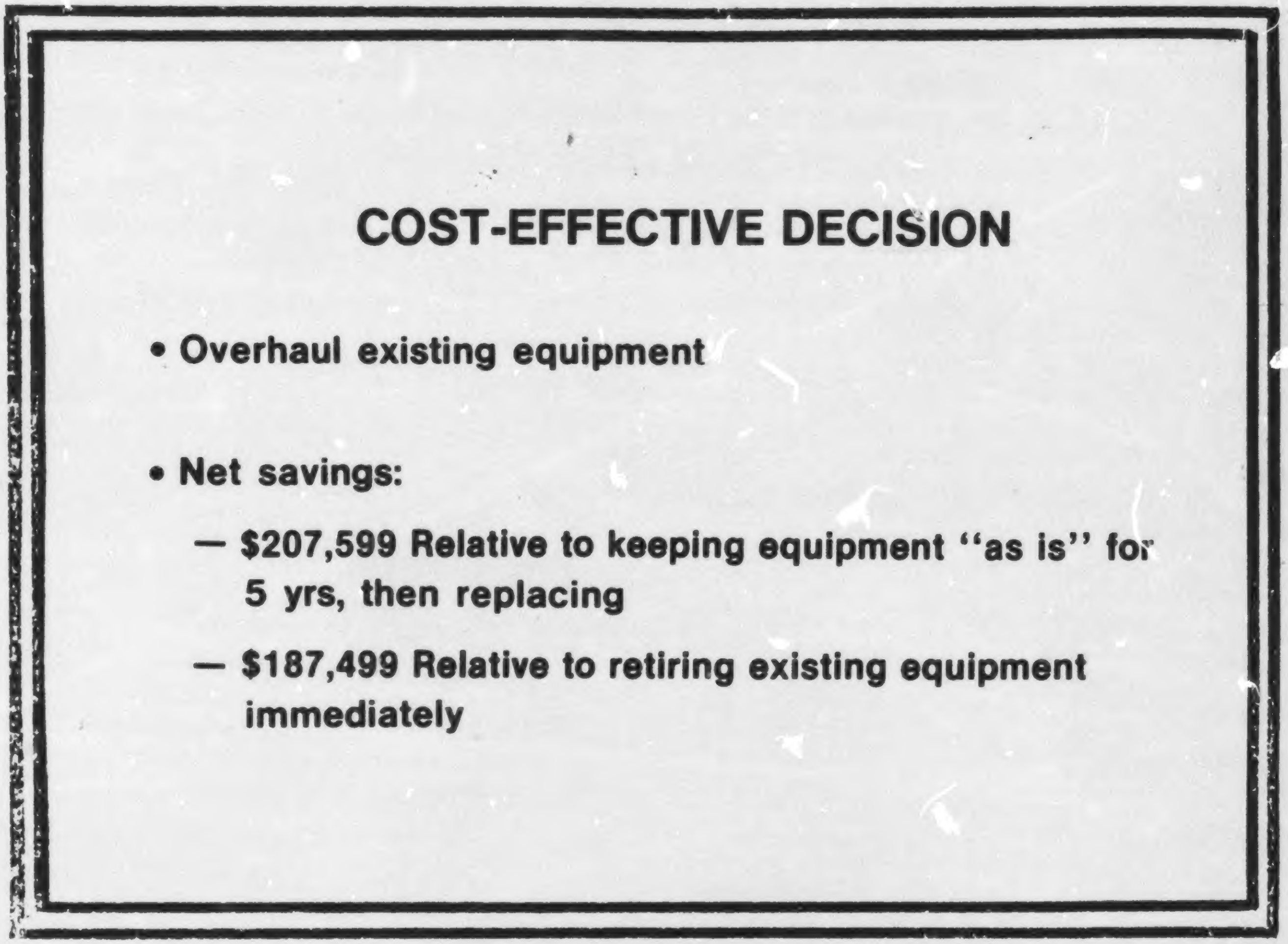
$$= \$50{,}000 + [0.85 \times 2{,}000{,}000 \times \$0.06 \times [4.73 + (1.28 \times 11.53 \times 0.71)]]$$

$$= \$1{,}601{,}263$$

Overhaul Existing Equipment

- o Show how the present value of this alternative is calculated.

Slide 6



COST-EFFECTIVE DECISION

- Overhaul existing equipment
- Net savings:
  - — $207,599 Relative to keeping equipment "as is" for 5 yrs, then replacing
  - — $187,499 Relative to retiring existing equipment immediately

Cost-Effective Decision

o Point out which alternative action results in lowest present value cost.

Section 24

Team Critique of an Economic Evaluation Report

The purpose of this exercise is to give workshop participants the experience of analyzing an economic report in a team context. The report contains common errors in problem formulation (defining objectives and alternatives), selection of assumptions, application of techniques (analysis), and presentation of recommendations.

Establish teams of three to six members, with each team composed of persons who normally do not work together. Ask each team to select a representative to present to the class the team's recommendations for an improved report.

Give the teams about 30 minutes to complete their analysis. Then call on a team representative for suggestions in the first category (i.e., problem formulation). Ask other representatives for additions and comments. Include all of the potential errors listed below that the teams overlook. Ask another representative for suggestions regarding the second category (i.e., selection of assumptions) and continue that process until all categories are covered.

Question the class about the following possible errors if they fail to identify them in their presentations.

1. Problem Formulation

    1.1 Is it likely that maximizing net savings with a limited budget is the sole objective of the agency?

    1.2 Is it appropriate to ignore alternatives whose benefits and costs are difficult to compute?

2. Assumptions and Data

2.1 How will different study periods affect the analysis?

2.2 What is wrong with using different discount rates? A rate different from 7%?

2.3 Is it correct to discount future costs expressed in current dollars with a real rate?

2.4 Are current dollars acceptable in FEMP?

2.5 Does the total budget have to be spent? For example, would remaining funds have to be returned?

3. Analysis

3.1 Should the SIR be used instead of NS to rank projects?

3.2 Does a payback of less than four years mean that projects are cost effective?

3.3 Is the documentation (footnote "a" of table 1) on underlying data sufficient to decide if the economic measures were computed properly?

3.4 Should possible interdependencies between conservation retrofits (e.g., storm windows and insulated window drapes) be considered?

3.5 How are costs adjusted for the .9 factor?

4. Recommendations

4.1 Is the reason for rejecting the use of cool night air appropriate?

4.2 Are the recommended alternatives economically efficient? Were they chosen for the right reasons?

4.3 Would it be economical to invest excess money (i.e., remaining funds) in partial accomplishment of some of the alternatives? For example, some windows could have storm windows and drapes added.

Conclude with the following analysis of what conservation alternatives would be economically efficient with each budget situation:

ERRATA SHEET FOR NBS Technical Note 1194

"ECONOMIC EVALUATION OF BUILDING DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE: INSTRUCTOR'S MANUAL,"
Replaces pp. 24-3 and 24-4
by Rosalie T. Ruegg and Harold E. Marshall

BEST COPY AVAILABLE

SUMMARY OF RECOMMENDATIONS[a]

Budget Level (1)	Package of Retrofits (2)	SIR for Each Retrofit (3)	First Cost of Retrofit Package (4) ≤ (1)	Total Life-Cycle Savings for Package (5)	Net Savings (6) = (5) - (4)
$92,000	Roof Insulation Flow Restrictors Time Clocks	20.4 18.3 4.2	$59,000	$334,000	$275,000
145,000	Time Clocks Storm Windows[b]	4.2 3.0	143,900	502,000	358,100
400,000	Roof Insulation Flow Restrictors Time Clocks Storm Windows Insulated Drapes	20.4 18.3 4.2 3.0 1.1	345,000	816,300	471,300

[a] The most economically efficient package of conservation retrofits for each budget level (as shown in the table) is that package which maximizes net savings (in present value terms). This may require passing over projects with high SIR's in favor of large projects with lower SIR's, as illustrated here with the $145,000 budget choice.

[b] An assumption in this table is that conservation projects such as storm windows cannot be done in smaller segments with remaining funds.

Energy Conservation Feasibility Study

Federal Building I
Washington, D.C.

Submitted by
XYZ Associates
Contractors Park, USA

[Note: This is purely a hypothetical example intended only as an instructional aid for illustrating important elements of an economic evaluation report.]

1. Objective and Scope

This report analyzes six alternatives for reducing utility costs in Federal Building I, an existing office building in Washington, D.C. The report provides GSA decision makers with economic guidance as to which conservation retrofits to select in light of the GSA objective of maximizing net savings from energy conservation subject to budgeting constraints.

2. Alternatives

The six alternatives are time clocks for lighting control, additional roof insulation, storm windows on the North side, flow restrictors for saving hot water in restrooms, use of cool night air to precool the building during the summer, and insulated window drapes. Other alternatives were considered, but they were rejected because their savings were difficult to calculate.

3. Assumptions and Data

A study period of 25 years is used for energy retrofits, and a study period of 20 years is used for the flow restrictors.

A real discount rate of 10% is used for evaluating the roof insulation and time clocks, and a real discount rate of 13% is used for the rest of the retrofits.

All future costs that are discounted to present values are stated in current dollars to account for inflation.

The report evaluates retrofits for the 1984 budget year. Since agency funding for 1984 is not yet determined, three budget levels covering the range that might be expected are assumed as follows: $92,000; $145,000; and $400,000. An economically efficient set of retrofit projects is selected for each of the three budget levels.

Occupant satisfaction with the building in terms of thermal comfort, lighting levels, and water supply are assumed to be unaffected by the proposed retrofits.

4. Analysis

The conservation retrofits are arranged in descending order of their cost effectiveness. Since the objective is to maximize net savings from conservation retrofits, column 4 (net dollar savings) determines the ranking of the six projects.

All projects except using cool night air to precool buildings in the summer are estimated to be cost effective in the sense that the SIR is greater than 1.0 and the payback is less than four years.

To maximize net savings under each of three budget scenarios, each project should be selected in the order given by column 5 until net savings become zero or negative, or until the budget is exhausted.

Table 1. Summary of Conservation Retrofits

Retrofit	Total Life-Cycle Cost Savings [a] $ (1)	First Cost $ (2)	SIR (3)=(1)÷(2)	Net Savings $ (4)=(1)-(2)	Economic Priority (5)
Storm Windows on North Side	276,000	90,500	3.0	185,000	1
Time Clocks for Lighting Control	226,000	53,400	4.2	172,600	2
Flow Restrictors in Restrooms	55,000	3,000	18.3	52,000	3
Roof Insulation	53,000	2,600	20.4	50,400	4
Insulated Window Drapes	206,300	195,500	1.1	10,800	5
Cool Night Air to Precool Building in Summer	130,000	140,000	0.9	-10,000	6

[a] The data and calculations that underly the cost and savings figures in this table are available from a research assistant at XYZ Associates.

5. Recommendations

For a budget of $92,000, storm windows on the North side of the building should be installed. Storm windows yield the greatest net benefits. The $1,500 remaining is insufficient to undertake any of the other projects.

For a budget of $145,000, both the storm windows and the time clocks should be installed. The $1,000 remaining is insufficient to undertake any other project.

For a budget of $400,000, all of the projects except using cool night air to precool the building in summer should be selected. Having a budget larger than the cost of all available alternatives is equivalent to having no budget constraint. Therefore any project with a relatively large SIR should be undertaken. Using cool night air is rejected because its SIR is lower than any of the other retrofits. For this reason it would not be acceptable regardless of the budget size.

Appendix A

Sample
Seminar Agenda

Day 1

8:45	Preliminaries
9:00	Introduction to the Seminar (Section 1)*
9:30	Fundamentals of Benefit-Cost and LCC Analysis (Section 2)
10:15	Break
10:30	Class Problems in Discounting (Section 11)
11:00	LCC, NB, NS, BCR, SIR, IRR, and PB Analysis
12:00	Lunch
1:15	Pipe Insulation Retrofit Problem (Section 5)
2:15	Break
2:30	Programmable Time Clock Problem (Sections 10 and 11)
3:30	Review and Discussion
4:15	Adjournment

* References in parentheses are to sections of the Workbook.

Day 2

8:45 Review of 1st Day Material - Questions and Answers

9:15 Determining Project Priority

9:45 Water Conservation Problem (Sections 10 and 12)

10:30 Break

10:45 Project Design, Sizing, and Selection

11:15 Treatment of Cost Escalation

12:00 Lunch

1:00 Team Problem - Planning an Energy Conservation Package (Sections 10 and 12)

2:15 Sensitivity and Probability Analysis (Sections 6 and 7)

2:30 Break

2:45 Problem in Sensitivity Analysis (Section 13)

3:00 Problem in Probability Analysis (Section 13)

3:30 Choosing a Study Period (Section 4)

3:45 Adjournment

Day 3

8:45 Review of 1st and 2nd Day Material - Questions and Answers

9:15 Break-Even Analysis (Section 8)

10:00 Team Problem - Break-Even Analysis in Support of a Labor/Machine Decision for Procurement (Section 14)

10:30 Break

10:45 Computer Room Waste Heat Recovery Problem (Sections 10 and 12)

12:00 Lunch

1:15 Replacement, Retirement, and Obsolescence (Section 9)

1:45 Team Problem - Determining Optimal Retirement of Equipment (Section 14)

2:15 Break

2:30 Team Critique of an Economic Evaluation Report (Section 15)

3:20 Group Discussion of Economic Evaluation for Building Decisions

3:45 Adjournment

Appendix B

Selected References

The American Institute of Architects, *Life-Cycle Cost Analysis: A Guide for Architects* (Washington, D.C.: 1977).

Booz-Allen and Hamilton, Inc., *Life-Cycle Costing in the Public Building Service*, prepared for the General Services Administration (Vol. I, 1976 and Vol. II, 1977).

Brown, Robert J. and Yanuck, Rudolph R., *Life Cycle Costing: A Practical Guide for Energy Managers* (Atlanta, Ga.: The Fairmont Press, Inc., 1980).

Dell'Isola, Alphonse J. and Kirk, Stephen J., *Life-Cycle Costing for Design Professionals* (New York, N.Y.: McGraw-Hill Book Company, 1981).

Executive Office of the President, Office of Management and Budget, "Comparative Cost Analysis for Decisions to Lease or Purchase General Purpose Real Property," Circular No. A-104 (June 14, 1972), Attachment.

Marshall, Harold E. and Ruegg, Rosalie T., *Energy Conservation in Buildings: An Economics Guidebook for Investment Decisions*, National Bureau of Standards Handbook Series 132 (Washington, D.C.: National Bureau of Standards, March 1980).

Marshall, Harold E. and Ruegg, Rosalie T., *Recommended Practice for Measuring Benefit/Cost and Savings-to-Investment Ratios for Buildings and Building Systems*, National Bureau of Standards Interagency Report 81-2397 (Washington, D.C.: National Bureau of Standards, November 1981).

Marshall, Harold E. and Ruegg, Rosalie T., *Simplified Energy Design Economics*, National Bureau of Standards Special Publication 544 (Washington, D.C.: National Bureau of Standards, January 1980).

Petersen, Stephen R., *Retrofitting Existing Housing for Energy Conservation: An Economic Analysis*, National Bureau of Standards BSS 64 (Washington, D.C.: National Bureau of Standards, 1974).

Reynolds, Smith & Hills, Architects--Engineers, Planners, *Life-Cycle Costing Emphasizing Energy Conservation; Guidelines for Investment Analysis*, Energy Research Development Administration Manual 76/130 (Revised May 1977).

Ruegg, Rosalie T. *et al.*, *Economic Evaluation of Solar Energy Systems in Commercial Buildings: Methodology and Case Studies*, National Bureau of Standards Interagency Report 82-2540 (Washington, D.C.: National Bureau of Standards, July 1982).

Ruegg, Rosalie T., *Life-Cycle Cost Manual for the Federal Energy Management Program*, National Bureau of Standards Handbook Series 135 (Rev.) (Washington, D.C.: National Bureau of Standards, May 1982).

Ruegg, Rosalie T., McConnaughey, John S., Sav, G. Thomas and Hockenbery, Kimberly A., *Life-Cycle Costing: A Guide for Selecting Energy Consevation Projects for Public Buildings*, National Bureau of Standards Building Science Series 113 (Washington, D.C.: National Bureau of Standards, September 1978).

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET** *(See instructions)*	1. PUBLICATION OR REPORT NO. NBS TN 1194	2. Performing Organ. Report No.	3. Publication Date June 1984

4. TITLE AND SUBTITLE

Instructor's Manual
Economic Evaluation of Building Design, Construction, Operation and Maintenance

5. AUTHOR(S)

Rosalie T. Ruegg and Harold E. Marshall

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

7. Contract/Grant No.

8. Type of Report & Period Covered

Final

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Design Programs Branch
Public Building Service
General Services Administration
Washington, DC 20405

BEST COPY AVAILABLE

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This instructor's manual describes each section of a three-day technical seminar on how to measure the economic impact of alternative designs, systems, and operation and maintenance strategies in Federal buildings. The manual was prepared to help instructors of the General Services Administration conduct technically sound and comprehensive seminars. For each technical session, the manual provides an introduction explaining the purpose of that session followed by copies of each visual and an outline of the commentary that would accompany that visual. The seminar covers the fundamentals of life-cycle cost, benefit-to-cost ratio, savings-to-investment ratio, internal rate of return, and payback analyses; sensitivity and probability analyses; break-even analysis; replacement decisions; and the solution of sample building problems that illustrate these economic evaluation methods. The sessions alternate between presentations of economic theory required for evaluating problems and actual problems that illustrate the economic evaluations in practice. Real building design problems with an emphasis on energy conservation are presented for individual and group solutions. The manual describes step-by-step how to present the problems and how to solve them. It presupposes an existing familiarity of the instructors with the basic concepts and evaluation techniques used in the seminars.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

building economics; cost effectiveness; decision analysis; design and construction; life-cycle costing; operation and maintenance; problem solving; project evaluation.

13. AVAILABILITY

☒ Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☒ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
☐ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

317

15. Price

NBS Technical Publications

Periodicals

Journal of Research—The Journal of Research of the National Bureau of Standards reports NBS research and development in those disciplines of the physical and engineering sciences in which the Bureau is active. These include physics, chemistry, engineering, mathematics, and computer sciences. Papers cover a broad range of subjects, with major emphasis on measurement methodology and the basic technology underlying standardization. Also included from time to time are survey articles on topics closely related to the Bureau's technical and scientific programs. As a special service to subscribers each issue contains complete citations to all recent Bureau publications in both NBS and non-NBS media. Issued six times a year.

Nonperiodicals

Monographs—Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

Handbooks—Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications—Include proceedings of conferences sponsored by NBS, NBS annual reports, and other special publications appropriate to this grouping such as wall charts, pocket cards, and bibliographies.

Applied Mathematics Series—Mathematical tables, manuals, and studies of special interest to physicists, engineers, chemists, biologists, mathematicians, computer programmers, and others engaged in scientific and technical work.

National Standard Reference Data Series—Provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated. Developed under a worldwide program coordinated by NBS under the authority of the National Standard Data Act (Public Law 90-396). NOTE: The Journal of Physical and Chemical Reference Data (JPCRD) is published quarterly for NBS by the American Chemical Society (ACS) and the American Institute of Physics (AIP). Subscriptions, reprints, and supplements are available from ACS, 1155 Sixteenth St., NW, Washington, DC 20056.

Building Science Series—Disseminates technical information developed at the Bureau on building materials, components, systems, and whole structures. The series presents research results, test methods, and performance criteria related to the structural and environmental functions and the durability and safety characteristics of building elements and systems.

Technical Notes—Studies or reports which are complete in themselves but restrictive in their treatment of a subject. Analogous to monographs but not so comprehensive in scope or definitive in treatment of the subject area. Often serve as a vehicle for final reports of work performed at NBS under the sponsorship of other government agencies.

Voluntary Product Standards—Developed under procedures published by the Department of Commerce in Part 10, Title 15, of the Code of Federal Regulations. The standards establish nationally recognized requirements for products, and provide all concerned interests with a basis for common understanding of the characteristics of the products. NBS administers this program as a supplement to the activities of the private sector standardizing organizations.

Consumer Information Series—Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

Order the **above** *NBS publications from: Superintendent of Documents, Government Printing Office, Washington, DC 20402.*

Order the **following** *NBS publications—FIPS and NBSIR's—from the National Technical Information Service, Springfield, VA 22161.*

Federal Information Processing Standards Publications (FIPS PUB)—Publications in this series collectively constitute the Federal Information Processing Standards Register. The Register serves as the official source of information in the Federal Government regarding standards issued by NBS pursuant to the Federal Property and Administrative Services Act of 1949 as amended, Public Law 89-306 (79 Stat. 1127), and as implemented by Executive Order 11717 (38 FR 12315, dated May 11, 1973) and Part 6 of Title 15 CFR (Code of Federal Regulations).

NBS Interagency Reports (NBSIR)—A special series of interim or final reports on work performed by NBS for outside sponsors (both government and non-government). In general, initial distribution is handled by the sponsor; public distribution is by the National Technical Information Service, Springfield, VA 22161, in paper copy or microfiche form.